

Dynamic Green Disclosure Requirements

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Deeksha Gupta

Johns Hopkins University

Jan Starmans

Stockholm School of Economics and ECGI

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Abstract

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Keywords: Socially responsible investing, sustainable investing, ESG, disclosure, non-financial reporting, greenwashing

JEL Classifications: G14, G18, G32, G38, M14

Deeksha Gupta

Assistant Professor of Finance
Johns Hopkins University
100 International Drive
Baltimore, MD 20036-1984, USA
e-mail: deeksha.gupta@jhu.edu

Jan Starmans*

Assistant Professor
Stockholm School of Economics, Department of Finance
Drottninggatan 98
111 60 Stockholm, Sweden
phone: +46 8 736 91 81
e-mail: jan.starmans@hhs.de

*Corresponding Author

Dynamic Green Disclosure Requirements*

Deeksha Gupta[†]

Jan Starmans[‡]

April 29, 2025

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[†]Carey Business School, Johns Hopkins University. Email: deeksha.gupta@jhu.edu.

[‡]Department of Finance, Stockholm School of Economics. Email: jan.starmans@hhs.se.

1 Introduction

Green disclosure requirements, which mandate companies to publicly report their sustainability efforts and environmental impact, have emerged as a prominent policy tool as the urgency to address climate change has intensified. These requirements represent one of the most significant shifts in corporate reporting in decades, with jurisdictions worldwide implementing sweeping new sustainability disclosure mandates. For instance, the European Union’s Corporate Sustainability Reporting Directive (CSRD) requires approximately 50,000 companies to report detailed sustainability information. Advocates of green disclosure regulation emphasize their importance in promoting transparency in financial markets to help support the economy’s green transition. For example, the European Union describes the Sustainable Finance Disclosure Regulation (SFDR) as a “transparency framework” that helps “investors who seek to put their money into companies and projects supporting sustainability objectives to make informed choices” with the main objective to “help Europe make the shift to a net-zero economy.” Intuitively, by giving investors pertinent information, green disclosure requirements may enable the efficient allocation of green capital, which may, in turn, incentivize firms to adopt sustainable practices.

As regulators worldwide implement extensive green disclosure requirements, they face fundamental questions about the design of these requirements. For example, how do these requirements affect stock prices and firm investment in green technologies? Should the requirements be as strict as possible to generate maximum transparency, or could there be benefits to limiting transparency? Should the requirements evolve and become stricter over time, like the EU’s SFDR and the SEC’s proposed climate disclosure rules? Further, how should factors such as the cost of investments in green technology and investors’ green preferences affect the design? Despite the potentially crucial role of these questions in policy design, research on green disclosure regulation is still in its early stages, and the efficacy and optimal design of green disclosure regulation remain open questions.

In this paper, we build a parsimonious framework to address these questions by studying the optimal design of green disclosure requirements to support firms’ green transition in a setting with socially responsible investors who value firms’ greenness.¹ We model a firm’s green transition

¹Our framework does not require pro-social preferences of investors. Alternatively, it can also capture investor concerns about physical or transition risks (e.g., Bolton and Kacperczyk, 2021b, 2022; Ilhan et al., 2023), consistent with the stated goal of some disclosure requirements to provide climate risk information (e.g., Carattini et al., 2022).

as a multi-step process without relying on specific assumptions about the costs and benefits of each transition step. This approach allows us to model the complex and dynamic nature of firms' green transition. In particular, our framework captures cases in which the early stages of the green transition process are particularly costly for firms, reflecting high fixed costs of investing in green technologies (e.g., Brown et al., 2024; Martinsson et al., 2024). These costs include writing down stranded assets, undertaking substantial capital expenditures on new green assets, or engaging in green research and development. High fixed costs of adopting green technologies can create potential roadblocks in the green transition, and our framework allows us to investigate whether and how green disclosure requirements can help overcome such roadblocks.

We establish an important link between the underlying characteristics of the technologies driving the green transition and the design of green disclosure requirements. We show that dynamic green disclosure requirements that become more stringent over time can dominate full transparency. When the initial stages of the green transition are very costly for firms, a regulator may benefit from initially implementing lax green disclosure requirements that obscure firms' true level of greenness. This deliberate obfuscation, which we refer to as "government-mandated greenwashing," creates a mis-valuation subsidy that generates additional incentives for firms to overcome roadblocks in the early stages of the green transition. While the initial lax stage encourages early steps in the green transition process, moving to more stringent requirements in the future incentivizes firms to undertake later stages.

We further show that dynamic green requirements can create an amplification effect because the stringency of green disclosure requirements interacts over time. The expectation of stricter requirements in the future can increase the efficacy of initially lax requirements. More specifically, a greater number of firms undertake the initial stages of the green transition when the lax phase of requirements is expected to be temporary rather than permanent. In addition, a greater number of firms undertake the later stages of the green transition when the stringent phase of requirements occurs after an initial period of lax green disclosure. Finally, we demonstrate that dynamic green disclosure requirements may slow down the green transition for some firms while increasing the total number of firms that eventually reform, highlighting a novel trade-off between the pace and breadth of the green transition.

More specifically, we consider an infinite-horizon environment in which a continuum of firms is born at the beginning of the first period. A representative socially responsible investor is endowed with each firm's shares. Each firm is initially one of three types—dirty, low-type green, or high-type green. All firms generate a random per-period profit with the same expected value. In addition, each firm generates a social benefit at the end of each period, with high-type green firms generating the highest social benefit and dirty firms generating the lowest. Complete green transition involves first paying a cost to adopt a green technology, which transitions a dirty firm to a low-type green firm, and then paying a cost to scale the green technology, which transitions a low-type green firm to a high-type green firm. We assume that a complete green transition is socially optimal.

Adoption may capture a firm's investment in relevant human capital for the green transition, engagement in green research and development, search for greener suppliers, phase out of polluting assets and technologies, acquisition of greener assets and technologies, and initial implementation of more sustainable practices and technologies within specific product categories. Scaling may involve deploying the expertise, assets, technologies, and practices from the adoption stage across all products and throughout the whole supply chain. Our model can also be applied to investment funds targeted by disclosure regulations such as the SFDR. In this context, adoption may involve building an investment team capable of developing active engagement strategies to promote sustainability within portfolio companies and the initial deployment of these strategies. Scaling may involve implementing these strategies across all portfolio companies and asset classes.

The central friction in our model is that the investor cannot observe a firm's type in the absence of green disclosure requirements. A firm's type is privately known to a manager who operates the firm and makes investment decisions to maximize the investor's firm valuation. The investor is socially responsible in that they internalize a fraction of the firms' social benefits. Such preferences have several interpretations and can capture investors who inherently care about externalities, are concerned about physical or transition risks, or value the additional profits coming from pro-social consumers.

A regulator aims to maximize the expected discounted aggregate social surplus in the economy and holds the authority to introduce green disclosure requirements before firms are born. While we present these requirements as mandatory rules that firms must follow, they can alternatively be

interpreted as a voluntary disclosure framework that allows firms to disclose according to specified standards, with the regulator being a certifier of the disclosed information. The regulator sets initial green disclosure requirements and can change them with some probability in each future period.

We start our analysis by characterizing firm adoption and scaling decisions under the full transparency benchmark—strict green disclosure, wherein all firms are mandated to disclose their respective types at the end of each period. The notion that increased transparency through green disclosure can create incentives for the green transition is present in our framework. In particular, the manager of a low-type green firm scales the green technology if the gain in the investor’s valuation from scaling and becoming a high-type green firm exceeds the scaling cost. The manager of a dirty firm has an additional consideration besides only the increase in the firm’s valuation when deciding whether to adopt the green technology. In particular, adopting the green technology also gives rise to the option to scale the green technology. This option value of scaling, which captures the prospect of further valuation increases, can serve as an additional incentive for firms to adopt the green technology. Importantly, this option value arises because we model green transition as a multi-step process in which firms must first adopt the green technology before scaling it.

Next, we consider the special case of time-invariant lax green disclosure under which low-type green and high-type green firms are pooled together in a single green disclosure category. While the transparency from strict green disclosure can induce firms to adopt or scale the green technology, we show that the regulator may be able to create better incentives for adoption alone—the first step in the green transition—by limiting transparency. Under strict green disclosure requirements, two forces drive adoption: the valuation gain from adoption alone and the option value of scaling. Time-invariant lax green disclosure requirements strengthen the former force while eliminating the latter. Under lax green disclosure requirements, the investor cannot differentiate between low- and high-type green firms. As a result, the valuation of a firm categorized as green is a weighted average of the valuations of low- and high-type green firms. This pooled valuation leads to an over-valuation of low-type green firms and an under-valuation of high-type green firms. Therefore, the benefit of adopting the green technology includes a mis-valuation subsidy, which strengthens the incentives of managers to adopt the green technology. However, low-type green firms never scale the green technology because scaling incurs a cost without increasing the investor’s valuation. Therefore, any option value of scaling is lost under time-invariant lax green

disclosure requirements.

We next study dynamic green disclosure requirements, which start with lax green disclosure in the first period and allow the regulator to switch to strict green disclosure with some probability in each future period. We first show that the regulator indeed finds it optimal to switch to strict green disclosure in the future when given the option. Under dynamic green disclosure requirements, the valuation gain from adoption during the initial lax period weakly exceeds that under time-invariant lax disclosure. This higher valuation arises because scaling may occur in the future once strict requirements are enacted. The investor's valuation considers both the mis-valuation subsidy and the option value of future scaling. Intuitively, dynamic green disclosure preserves the option value of scaling lost under lax disclosure, thereby increasing the value of adopting the green technology.

Our analysis highlights an amplification effect of dynamic green disclosure arising from the interaction of strict and lax green disclosure requirements over time. This amplification arises from the multi-step nature of the green transition. We show that more firms adopt the green technology when lax requirements are temporary and expected to be followed by strict green disclosure than if lax requirements were expected to be permanent. The expectation of strict green disclosure in the future increases the effectiveness of lax green disclosure in creating adoption incentives by preserving the option to scale the green technology. Moreover, the initial period of lax green disclosure can amplify the impact of strict green disclosure requirements by creating a greater measure of low-type green firms that eventually scale the green technology. Therefore, the dynamic interaction of these two types of green disclosure requirements can create more adoption and scaling than would occur under only strict or lax green disclosure requirements.

While dynamic green disclosure requirements may best support the green transition, they can still involve a trade-off relative to having only strict green disclosure requirements. In particular, under dynamic green disclosure requirements, initially low-type green firms delay their scaling decision until green disclosure requirements become strict. As such, the regulator faces a trade-off between slowing down the green transition of some firms and incentivizing the green transition of others. Our analysis thus highlights a novel trade-off between the pace and the breadth of the green transition.

We explore a number of extensions. First, we analyze how voluntary green disclosure technology—

allowing some firms to credibly reveal their type at a cost—affects our results. Second, we consider the case where the investor receives informative signals about firms’ types independent of green disclosure. While both extensions reduce the effectiveness of dynamic green disclosure requirements in incentivizing adoption, they enable some firms to scale their green technology earlier. This highlights an important trade-off: increased transparency through voluntary disclosure or informative signals may reduce the breadth but increase the speed of the green transition.

In our main analysis, we focus on lax green disclosure requirements that pool low-type and high-type green firms. This approach aligns with real-world implementations, such as the EU’s SFDR, which initially distinguished between green and non-green funds before introducing stricter requirements that allowed investors to differentiate between light-green (Article 8) and dark-green (Article 9) funds. We extend our analysis and show that the dynamic green disclosure requirements from our baseline model are optimal, under reasonable assumptions, in a broader class of disclosure requirements that pool firms in alternative ways. Specifically, we additionally consider lax green disclosure requirements that pool dirty and low-type green firms or dirty and high-type green firms. We show that when scaling costs are not too high, the requirements in our main analysis continue to be optimal. This includes cases in which adoption costs are high and adoption, rather than scaling, is creating a roadblock in the green transition. We further show that if scaling, rather than adoption, is creating a roadblock in the green transition due to high scaling costs, the regulator may prefer to implement disclosure requirements that pool dirty and low-type green firms, as such disclosure creates a tax on low-type green firms that are not scaling. However, dynamic disclosure, which initially pools dirty and low-type green firms, does not exhibit a similar amplification effect between strict and lax requirements as in our main analysis. Given the evidence that is consistent with high upfront costs of initial green investments (e.g., Brown et al., 2024; Martinsson et al., 2024), adoption appears to be the major roadblock in the green transition. As such, the dynamic green disclosure requirements we study in our baseline model are more empirically relevant.

Our analysis highlights the importance of jointly considering green disclosure requirements and the underlying characteristics of the transition technology. A standard modeling assumption is that the transition technology exhibits diminishing returns to scale. If adoption is relatively inexpensive, strict green disclosure would be preferred to lax or dynamic, as adoption would not create a roadblock in the green transition. Our analysis demonstrates the significance of identifying

roadblocks within the transition process. In such cases, an initially laxer standard may be essential in overcoming roadblocks in the green transition process.

Recent policy initiatives align closely with our framework. The SEC’s proposed climate disclosure rules, California’s climate disclosure laws, the EU’s CSRD and SFDR, and the UK’s current proposals all become more stringent over time. For example, the SEC’s proposed climate disclosure rules mandate less detailed, more qualitative disclosures in the fiscal year 2025 and require more detailed disclosures relating to financial expenditures and greenhouse gas emissions starting in the fiscal year 2026 (Sasfai et al., 2024). Similarly, the SFDR initially required financial market participants to comply with less stringent “Level 1” disclosure requirements starting in January 2021. Two years later, in January 2023, the SFDR entered its “Level 2” phase in which disclosure requirements became more stringent, and entities were required to reveal more detailed information to investors (Deloitte, 2024). While practical motivations for this dynamic implementation may include political and administrative constraints, our model suggests that this approach may optimally encourage early investments necessary for the economy’s green transition. Consistent with our predictions, research finds decreased emission intensity during the SFDR’s less stringent initial phase (Emiris et al., 2024; Spaans et al., 2024). Our analysis suggests that the anticipation of stricter requirements could have increased incentives to become greener during the first phase. As such, a time-invariant disclosure standard resembling the SFDR’s initial but not its later phase may be less effective.

An important insight of our analysis is that the regulator may enhance the green transition by allowing for obfuscation in which less green firms are deliberately made indistinguishable from greener firms. This notion of government-mandated greenwashing differs from the traditional concept of firms intentionally misrepresenting their level of greenness. Amid growing concerns about greenwashing tricking investors,² this insight adds nuance by highlighting potential social benefits of obfuscation. An important empirical implication is that such obfuscation among firms does not necessarily mean these firms are failing to reduce externalities. In our model, dirty firms may enhance their social value while appearing greener than they are, with this ability to obfuscate being key to motivating reform. This contrasts with studies interpreting greenwashing as a lack of genuine reform (e.g., Dumitrescu et al., 2022; Duchin et al., 2025).

²See, for example, “A Broken System Needs Urgent Repairs,” *The Economist*, 21 July 2022.

While motivated by the rise in green disclosure regulation targeted at green investors, our framework has broader applications. First, it yields important implications for carbon taxation. When political constraints and other frictions prevent implementing Pigouvian taxes, regulators may benefit from complementing sub-optimal carbon taxes with disclosure requirements that temporarily obscure firms’ emissions levels during early transition stages, effectively reducing their tax burden. Second, our framework applies to disclosure about innovation investments more generally. Here, the social benefits can be reinterpreted as innovation spillovers that firms only partially internalize, with dynamic disclosure requirements helping incentivize early-stage innovation investments.

2 Related Literature

Our paper contributes to the theoretical literature studying how socially responsible investors impact firm decisions and real social or environmental outcomes (e.g., Heinkel et al., 2001; Hart and Zingales, 2017; Davies and Van Wesep, 2018; Chowdhry et al., 2019; Morgan and Tumlinson, 2019; Green and Roth, 2021; Matsusaka and Shu, 2021; Pastor et al., 2021; Roth, 2021; Barbalau and Zeni, 2022; Broccardo et al., 2022; Gollier and Pouget, 2022; Huang and Kopytov, 2022; Moisson, 2022; Allen et al., 2023; De Angelis et al., 2023; Döttling and Rola-Janicka, 2023; Edmans et al., 2022; Geelen et al., 2022; Jagannathan et al., 2022; Jin and Noe, 2023; Landier and Lovo, 2024; Levit et al., 2024; Bisceglia et al., 2023; Malenko and Malenko, 2023; Döttling et al., 2024; Gryglewicz et al., 2024; Oehmke and Opp, 2024; Gupta et al., 2025). We contribute to this literature by studying how green disclosure requirements can encourage the green transition in a dynamic environment with socially responsible investors.

While we study green disclosure requirements in a dynamic environment, a small group of papers examine green disclosure in a static setting (e.g., Lyon and Maxwell, 2011; Wu et al., 2020; Aghamolla and Byeong-Je, 2023; Chen and Schneemeier, 2023; Chen, 2023; Xue, 2023; Inderst and Opp, 2025).³ For example, Chen and Schneemeier (2023) study how voluntary green disclosure affects traders’ incentives to acquire information and trade on private information in a setting

³There is also a literature that studies certification by private entities (e.g., Albano and Lizzeri, 2001; Miklós-Thal and Schumacher, 2013; Azarmsa and Shapiro, 2023; Bizzotto and Harstad, 2023).

with feedback effects. In contrast to this literature on static green disclosure, we consider a dynamic environment where the green transition is a multi-step process, showing how disclosure requirements optimally evolve and interact over time. This dynamic interaction, arising from the multi-step nature of the green transition, contrasts with the static disclosure characterized in previous work. A notable exception in studying a dynamic setting is Cartellier et al. (2023), who analyze firms’ voluntary disclosure. Instead, we take a normative perspective by studying the regulator’s problem in designing green disclosure requirements.

Our work relates to a literature examining how regulators can facilitate firms’ green transition in the presence of green shareholders and financial frictions. Existing work focuses on standard policies like carbon taxes, carbon trading schemes, and emissions caps (e.g., Biais and Landier, 2022; Huang and Kopytov, 2022; Döttling and Rola-Janicka, 2023). For example, Döttling and Rola-Janicka (2023) show that optimal emission taxes deviate from the Pigouvian benchmark when firms are financially constrained. In contrast, we study green disclosure requirements as a new policy tool.

We also relate to theoretical work on how socially responsible investors and carbon regulation influence the pace of firm reform (Bustamante and Zucchi, 2022, 2024; Gupta et al., 2025).⁴ Gupta et al. (2025) show how investors with broad impact preferences may slow down the green transition by incentivizing strategic delay in firm reform, with investment mandates helping to speed up reform. Bustamante and Zucchi (2022, 2024) demonstrate how carbon pricing favors short-term over long-term pollution measures. In contrast, we focus on the effect of green disclosure requirements.

A growing body of empirical work examines the financial and real effects of green disclosure (e.g., Jouvenot and Krueger, 2019; Bolton and Kacperczyk, 2021a; Christensen et al., 2022; Giannetti et al., 2023; Ilhan et al., 2023; Parise and Rubin, 2023; Emiris et al., 2024; Krueger et al., 2024; Spaans et al., 2024). These papers support our assumptions about disclosure and socially responsible investing and provide empirical support for key predictions. Emiris et al. (2024) and Spaans et al. (2024) show that investors respond to mandatory green disclosure by increasing green

⁴More broadly, we also relate to dynamic models studying how to incentivize agents to take certain actions by changing the information environment (e.g., Che and Mierendorff, 2019; Bar-Isaac and Deb, 2020; Ely and Szydlowski, 2020; Hörner and Lambert, 2020; Dai et al., 2024). These papers study optimal contract design in principal-agent models with agency problems in settings in which the principal has private information. In contrast, we study a regulator’s problem in a setting without agency problems between the manager and shareholders and in which the manager—the agent taking the action—has full information.

fund investment, while Ilhan et al. (2023) demonstrates investor flow responses to voluntary green disclosure. Additionally, Emiris et al. (2024) and Spaans et al. (2024) find funds reduce their emission intensity during SFDR’s initial lax stage, supporting our prediction that lax green disclosure can encourage funds to become greener.

Finally, we relate to the literature on the benefits of limiting information in markets (e.g., Vives, 1984; Gal-or, 1987, 1988), rating coarseness (e.g., Lizzeri, 1999; Doherty et al., 2012; Goel and Thakor, 2015; Kartasheva and Yilmaz, 2020; Ali et al., 2022; Biswas et al., 2023), and bank stress testing showing optimal pass-fail disclosure (e.g., Goldstein and Leitner, 2018). These papers examine static settings where information frictions affect investor welfare. A notable exception is Orlov et al. (2023), who highlight that a sequential stress testing design, which involves recapitalizing banks before a stress test and then conducting a more informative stress test, can dominate a static stress test. In contrast, we study a dynamic setting with corporate externalities and a multi-step transition process.

3 Model

We consider an infinite-horizon environment, where a period is denoted by $t \in \mathbb{N}_0 := \{0, 1, \dots\}$. Firms are owned by a representative investor and operated by managers who make investment decisions to maximize the investor’s firm valuations. The investor is risk-neutral and has the time-discount factor $\beta \in (0, 1)$ between periods.

At the beginning of period $t = 0$, a unit continuum of firms is born, and the representative investor is endowed with each firm’s shares. There are three types of firms: dirty firms (d), low-type green firms (g_L), and high-type green firms (g_H). The masses of the three types of firms at the beginning of period $t = 0$ are denoted by $\mu_d > 0$, $\mu_{g_L} > 0$, and $\mu_{g_H} > 0$, where $\mu_d + \mu_{g_L} + \mu_{g_H} = 1$.⁵ Each firm generates a random and independent profit $\tilde{\pi}$ with expected value $\pi := \mathbb{E}[\tilde{\pi}] > 0$ at the end of each period, which is independent of its type. Each firm also generates a type-dependent social benefit b_i , where $i \in \{d, g_L, g_H\}$. The social benefit can be positive (e.g., carbon capturing) or negative (e.g., carbon emissions), with the only requirement being that $b_{g_H} > b_{g_L} > b_d$. We

⁵In Section 8, we discuss microfoundations that can give rise to an initial distribution of firm types.

denote $\Delta_a = b_{gL} - b_d > 0$ and $\Delta_s = b_{gH} - b_{gL} > 0$.

There is a green technology that allows firms to change their type by increasing the social benefit they generate. A dirty firm can adopt the green technology by paying a one-time adoption cost $\kappa_a > 0$ to become a low-type green firm. For example, this adoption cost can represent the fixed costs of initial green investments. A low-type green firm can scale the green technology by paying a one-time scaling cost $\kappa_s > 0$ to become a high-type green firm. For example, scaling may involve deploying green expertise and technology across all products and throughout the supply chain. Dirty firms can, but do not have to, adopt and scale the green technology in the same period. Our framework can capture cases where scaling is more costly than adoption, consistent with standard diminishing returns to scale. However, our framework also accommodates cases where adoption is more costly than scaling, capturing the idea that early stages of the green transition are particularly costly. This can create potential roadblocks in the green transition process, consistent with evidence indicating that high-emitting firms require substantial upfront investments in the green transition (e.g., Brown et al., 2024; Martinsson et al., 2024). We assume that both adoption and scaling are irreversible.⁶

The expected discounted social surplus generated by a firm of type $i \in \{d, g_L, g_H\}$ that never changes its type is $\sum_{t=0}^{\infty} \beta^t (\pi + b_i) = \frac{\pi + b_i}{1 - \beta}$. We assume it is socially optimal for firms to adopt and scale the green technology:

$$\frac{\pi + b_{gL}}{1 - \beta} - \kappa_a > \frac{\pi + b_d}{1 - \beta} \Leftrightarrow \frac{\Delta_a}{1 - \beta} > \kappa_a \quad \text{and} \quad \frac{\pi + b_{gH}}{1 - \beta} - \kappa_s > \frac{\pi + b_{gL}}{1 - \beta} \Leftrightarrow \frac{\Delta_s}{1 - \beta} > \kappa_s.$$

The first assumption implies that adoption alone, even without further scaling, is socially preferable to not adopting the green technology. Additionally, we assume that it is not socially desirable to shut down a dirty firm, meaning that the expected per-period social surplus generated by a dirty firm, $\pi + b_d$, is positive.

A firm's social benefit impacts the representative investor's utility and, therefore, firm valuations. Specifically, the investor's per-period expected utility from a type i firm under full information is $\pi + \lambda b_i$, where $\lambda \in (0, 1]$. When $\lambda = 1$, the investor internalizes the entire social benefit. A

⁶In Section 8, we discuss the implications of partial reversibility for our results.

representative investor is a simple and tractable way to model a premium for green firms.⁷ Many papers provide evidence that green firms have higher market valuations (e.g., Bolton and Kacperczyk, 2021b, 2022; Ilhan et al., 2023; Eskildsen et al., 2024). We are agnostic about why the representative investor values greener firms more and only require that firm valuations increase with the firm’s greenness under full information. This may capture investors inherently caring about externalities, concerns about physical or transition risks, or additional profits coming from pro-social consumers.⁸

Each manager makes adoption and scaling decisions to maximize the expected end-of-period firm value, implying that the manager is maximizing the market value of the firm based on the investor’s information set. Such preferences can be micro-founded by managerial concerns arising from stock-based compensation and is a standard assumption in the sustainable finance literature (e.g., Pastor et al., 2021).⁹ For example, under full information, the end-of-period $t = 0$ valuation of a low-type green firm that scales the green technology in period $t = 0$ is

$$\hat{\pi} - \kappa_s + \lambda b_{gH} + \frac{\beta}{1 - \beta} (\pi + \lambda b_{gH}),$$

where $\hat{\pi}$ is the realized and π the expected profit. Intuitively, this captures the investor’s valuation, based on their information set, on the day of the firm’s earnings announcement. The expected end-of-period valuation for a firm that scales the green technology is thus $\frac{\pi + \lambda b_{gH}}{1 - \beta} - \kappa_s$.¹⁰ Under full information, the manager of a low-type green firm will scale the green technology if

$$\frac{\pi + \lambda b_{gH}}{1 - \beta} - \kappa_s \geq \frac{\pi + \lambda b_{gL}}{1 - \beta} \Leftrightarrow \frac{\lambda \Delta_s}{1 - \beta} \geq \kappa_s.$$

As such, the adoption and scaling decisions of each manager will depend on the investor’s infor-

⁷A number of papers derive this premium as an equilibrium result in asset pricing models with both financial and socially responsible investors (e.g., Heinkel et al., 2001; Pastor et al., 2021; Pedersen et al., 2021).

⁸In Section 8, we discuss the mapping of the model assumptions to different micro-foundations for green preferences in more detail.

⁹In Section 8, we discuss additional implications that would arise if, in addition to the investor, the manager also had pro-social preferences. We also discuss what happens if the manager cares about future changes in firm valuation based on their private information besides the expected end-of-period firm value.

¹⁰We assume that a firm’s manager makes adoption and scaling decisions before the random profit is realized. The manager’s adoption and scaling decisions would be identical if we instead assumed that the manager makes adoption and scaling decisions after profits are realized but before they are reported to the investor.

mation set and the degree to which the investor internalizes the social benefit, λ .

The central friction is that the investor cannot observe firms' types and their adoption and scaling decisions without green disclosure requirements. In practice, green technologies may involve investments that are not easily discernible from financial statements and require specific sustainability disclosure. Consistent with the presence of significant information asymmetries regarding firms' greenness in financial markets, many studies provide evidence of investor demand for sustainability disclosure through shareholder proposals requesting such disclosures (e.g., Fisch and Robertson, 2024) and trading activity and valuation changes following green disclosure events (e.g., Jouvenot and Krueger, 2019; Bolton and Kacperczyk, 2021a; Christensen et al., 2022; Giannetti et al., 2023; Ilhan et al., 2023; Parise and Rubin, 2023; Emirir et al., 2024; Krueger et al., 2024; Spaans et al., 2024). Specifically, we assume that the investor observes only the realization of the random variable $\tilde{\pi} - \kappa$ at the end of a period, where $\kappa \in \{\kappa_a, \kappa_s, \kappa_a + \kappa_s, 0\}$, but not its components. For simplicity, we assume that $\tilde{\pi}$ is sufficiently noisy to prevent inference about κ .¹¹ In addition, while managers are informed about the firm's type and actions, they cannot credibly convey this information to the investor without green disclosure requirements. Section 7.1 extends the model to allow for voluntary green disclosure.

A regulator can establish green disclosure requirements, which determine the investor's information set regarding firm types.¹² In the baseline model, we consider two possible types of green disclosure requirements: strict green disclosure that discloses all firms' types at the end of each period and lax green disclosure that pools green firms—i.e., high-type and low-type green firms—in a pooled disclosure category.

The regulator establishes initial green disclosure requirements in period $t = 0$, and they can

¹¹To illustrate this more formally, consider a scenario without green disclosure where all dirty firms adopt the green technology and assume profits are normally distributed. The inference problem of distinguishing dirty from initially green firms then becomes one of two normal distributions with known common variance σ^2 and means π and $\pi - \kappa_a$. With probability $1 - \mu_d$, a draw is made from $N(\pi, \sigma^2)$, and with probability μ_d , from $N(\pi - \kappa_a, \sigma^2)$. After observing a realization, the posterior probability of having drawn from either distribution can be updated using Bayes' Rule. As $\sigma^2 \rightarrow \infty$, the posterior probabilities converge to the prior probabilities because the observation becomes uninformative, and the prior dominates. In Section 7.2, we extend the model to allow for the possibility that the investor can learn about a firm's type from signals independent of green disclosure requirements.

¹²While represented as mandatory rules, these can be interpreted as a voluntary framework with regulatory certification. The equilibria in our model can be sustained in this extended framework under the off-equilibrium belief for non-disclosing firms that they are dirty firms. This belief is consistent with the intuitive criterion refinement, as dirty firms have the strongest incentive among all firm types to deviate to nondisclosure.

switch requirements with probability $\rho \in [0, 1]$ at the beginning of each period $t > 0$. As such, if the regulator implements lax green disclosure in period $t = 0$, they can switch from lax to strict green disclosure with probability ρ at the beginning of each future period. We do not consider switches from strict to lax green disclosure since revealed public information cannot be reversed. This type of dynamic disclosure aligns with real-world implementations, such as the EU’s SFDR, which initially distinguished between green and non-green funds before introducing stricter requirements that allowed investors to differentiate between light-green (Article 8) and dark-green (Article 9) funds. The parameter ρ captures institutional frictions in changing regulation, reflecting delays from political opposition or legal constraints. For example, the EU postponed CSRD reporting deadlines for some firms due to industry resistance (Schwartzkopff, 2024), and SFDR’s Level 2 requirements continue evolving even after entering this stage in January 2023 (Müller and Illarionova, 2023). We assume the regulator cannot commit to a future switch to strict green disclosure in period $t = 0$.¹³

In Section 7.3, we show that the dynamic green disclosure requirements we study in our baseline model are optimal, under reasonable assumptions, in a broader class of disclosure requirements that pool firms in alternative ways. Specifically, we demonstrate the robustness of our main results by considering the two additional lax green disclosure requirements that may arise in our model: those that pool dirty and low-type green firms and those that pool dirty and high-type green firms.

The regulator’s objective is to maximize the expected discounted aggregate social surplus. They set initial requirements at the beginning of period $t = 0$, with classifications disclosed at the end of each period. As a result, firms can take an action—adopt or scale—before their type is disclosed. Note that the assumption of nondisclosure of initial firm types at the beginning of period $t = 0$ is without loss of generality, as the regulator always weakly prefers no initial disclosure. We discuss the implications of historical disclosure further in Section 8. We extend the model to incorporate credible voluntary disclosure and public signals about firm types to capture cases in which there may be information leakage about firm types despite the regulator choosing limited transparency about firms’ greenness in Section 7. Figure 1 summarizes the sequence of events.

Notably, while a Pigouvian tax under full transparency could implement the first-best allocation

¹³As we discuss in Section 6, the results of our baseline model are identical whether or not we assume commitment to future disclosure regulation on the side of the regulator.

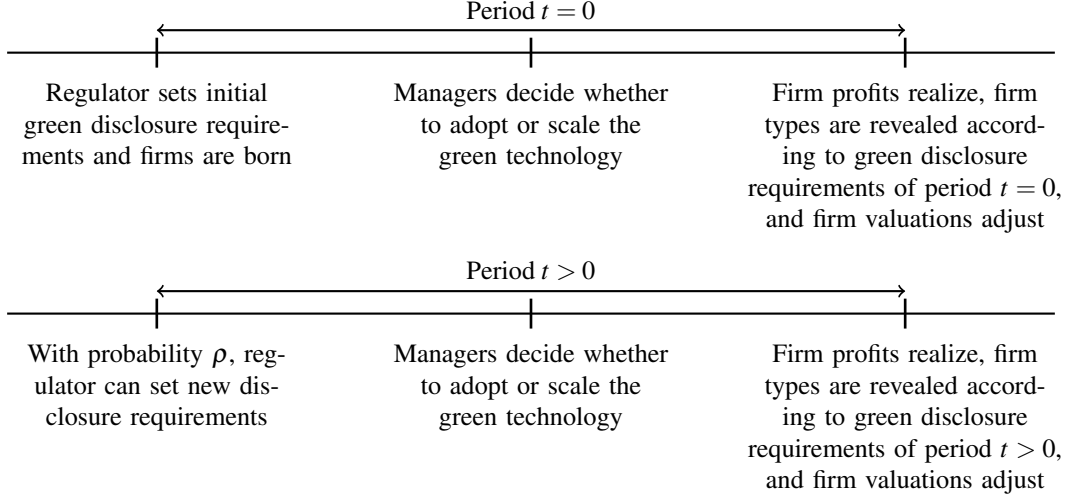


Figure 1: Sequence of events during the first period $t = 0$ and any future period $t > 0$.

in our framework, informational frictions, political economy constraints, and public opposition prevent effective carbon taxes (e.g., Acemoglu et al., 2012; Tirole, 2012; Carattini et al., 2019; Douenne and Fabre, 2022; Döttling and Rola-Janicka, 2023; Oehmke and Opp, 2024), creating a need for other complementary regulatory interventions. This may partly explain regulators' turn to disclosure regulation, which may be more feasible to implement by leveraging financial market demand rather than direct taxation. Section 8 discusses applying our model to carbon taxation, interpreting $\lambda < 1$ as a constrained tax and giving rise to a complementarity between taxation and green disclosure regulation.

The remainder of the paper proceeds as follows. Section 4 analyzes strict green disclosure, which, by its nature, is time-invariant. To build intuition for the main mechanism, Section 5 studies the special case when $\rho = 0$ and lax disclosure is time-invariant. Section 6 presents our main results on dynamic green disclosure requirements. Section 7 extends the model by exploring voluntary disclosure and information signals and demonstrates the robustness of our main results to a broader class of disclosure requirements that allow for pooling of firms in arbitrary ways. Section 8 discusses implications and further robustness. All proofs are in the appendix.

4 Strict Green Disclosure Requirements

This section studies full transparency as a benchmark to understand when it generates sufficient adoption and scaling incentives to facilitate firms' green transition.

Under strict green disclosure requirements, the investor observes a firm's type at the end of each period. The manager maximizes the expected end-of-period valuation, making adoption and scaling decisions before profits are realized. A low-type green firm's manager scales the green technology at $t = 0$ if the valuation gain, $\frac{\lambda\Delta_s}{1-\beta}$, weakly exceeds the scaling cost, κ_s .¹⁴

Lemma 1. *Under strict green disclosure requirements, the manager of a low-type green firm scales the green technology in period $t = 0$ if and only if $\frac{\lambda\Delta_s}{1-\beta} \geq \kappa_s$, where $\frac{\lambda\Delta_s}{1-\beta}$ represents the valuation gain from scaling and κ_s represents the scaling cost.*

Clearly, the manager of a dirty firm adopts the green technology at $t = 0$ if the resulting valuation gain from adoption alone, $\frac{\lambda\Delta_a}{1-\beta}$, weakly exceeds the adoption cost, κ_a . Even if this is not the case, the manager may still adopt the green technology because it gives rise to the option to scale the green technology. If this option value is significant enough, the manager will adopt the green technology.¹⁵

Lemma 2. *Under strict green disclosure requirements, the manager of an initially dirty firm adopts the green technology in period $t = 0$ if and only if*

$$\frac{\lambda\Delta_a}{1-\beta} + \max \left\{ \frac{\lambda\Delta_s}{1-\beta} - \kappa_s, 0 \right\} \geq \kappa_a, \quad (1)$$

where $\frac{\lambda\Delta_a}{1-\beta}$ represents the valuation gain from adoption alone, $\frac{\lambda\Delta_s}{1-\beta}$ represents the valuation gain from scaling, and κ_a and κ_s represent the adoption and scaling costs, respectively.

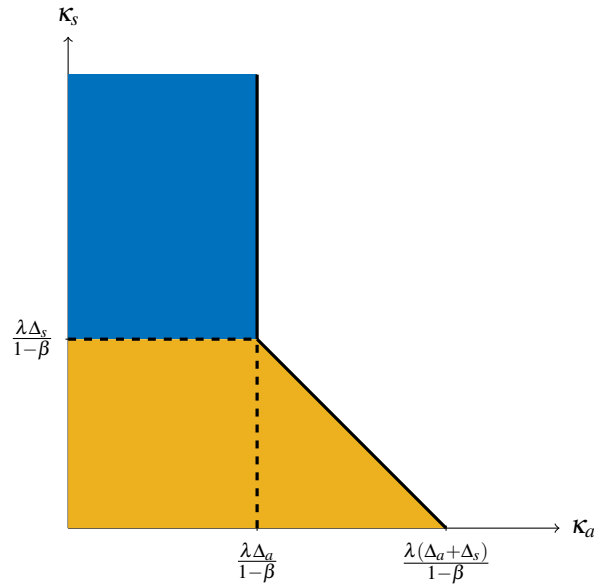
Figure 2 illustrates adoption and scaling decisions as functions of their costs. The blue region shows where dirty firms adopt but do not scale the green technology, characterized by low adoption but high scaling costs. In the yellow region, dirty firms both adopt and scale the green technology. Within this region, the rectangular area (adoption costs between 0 and $\frac{\lambda\Delta_a}{1-\beta}$) represents the cases

¹⁴The manager of a low-type green firm would never defer the scaling of the green technology under full information.

¹⁵The manager of a dirty firm would never defer the adoption of the green technology under full information.

in which the valuation gain from adoption alone is sufficient. The triangular area (adoption costs between $\frac{\lambda \Delta_a}{1-\beta}$ and $\frac{\lambda(\Delta_a+\Delta_s)}{1-\beta}$) represents cases where the valuation gain from adoption alone is not sufficient, but the option value of scaling drives adoption. Note that we allow firms to both adopt and scale the green technology in the same period, which is why the option value of scaling is not discounted.¹⁶ Section 8 discusses additional implications of risky scaling in further driving the adoption decision by changing the option value of scaling.

Figure 2: Adoption and Scaling of the Green Technology by a Dirty Firm under Strict Green Disclosure Requirements



Notes: The figure plots a dirty firm's adoption and scaling decisions under strict green disclosure requirements. The area in blue represents the region of parameters for which a dirty firm adopts the green technology but does not scale it. The area in yellow represents the region of parameters for which a dirty firm adopts and scales the green technology.

Corollary 1. *If $\lambda = 1$, then strict green disclosure requirements implement the first best. Specifically, initially dirty firms adopt and scale the green technology, and initially low-type green firms scale the green technology.*

This result follows directly from our assumption of adoption and scaling being socially optimal. When the investor fully internalizes social benefits, managers adopt and scale the green technology under full information, making strict green disclosure requirements optimal.

¹⁶Our results are qualitatively similar if we instead assume that adoption and scaling occur in separate periods.

In practice, firm valuations are unlikely to fully reflect social costs and benefits of the green transition (e.g., Berk and van Binsbergen, 2024; Eskildsen et al., 2024). Thus, we are interested in cases where $\lambda < 1$. It is worth noting that even if $\lambda < 1$, strict green disclosure (weakly) dominates no disclosure. Without disclosure, valuations cannot depend on the firm's type, eliminating incentives for adoption or scaling.

5 Time-Invariant Lax Green Disclosure Requirements

This section studies time-invariant lax green disclosure requirements, where the regulator cannot switch to strict requirements in the future (i.e., $\rho = 0$). In Section 5.1, we examine managers' adoption and scaling decisions. In Section 5.2, we study the regulator's choice between time-invariant lax and strict green disclosure requirements. This analysis provides the foundation for our main results on dynamic green disclosure requirements that become more stringent over time in Section 6.

5.1 Green Technology Adoption and Scaling

Under time-invariant lax green disclosure requirements, the investor's expected end-of-period $t = 0$ valuation of a firm in the green disclosure category is a weighted average of low-type and high-type green firm valuations. The weights depend on the proportions of low- and high-type green firms at the end of period $t = 0$, which, in turn, depend on dirty firms' adoption and low-type green firms' scaling decisions.

To derive this valuation, first note that low-type green firms never scale the green technology under time-invariant lax green disclosure requirements because scaling incurs a cost without increasing the investor's valuation.

Lemma 3. *Under time-invariant lax green disclosure requirements, low-type green firms never scale the green technology.*

Let $\phi \in [0, 1]$ denote the fraction of dirty firms that adopt the green technology in period $t = 0$.

The investor's expected end-of-period $t = 0$ valuation of a firm in the green disclosure category is

$$\frac{\pi + \frac{\phi\mu_d + \mu_{gL}}{\phi\mu_d + \mu_{gL} + \mu_{gH}}\lambda b_{gL} + \frac{\mu_{gH}}{\phi\mu_d + \mu_{gL} + \mu_{gH}}\lambda b_{gH}}{1 - \beta} - \kappa, \quad (2)$$

where $\kappa = \kappa_a$ if the firm incurred the adoption cost and $\kappa = 0$ otherwise. The investor bears adoption costs through reduced profits, which managers consider in their decisions. However, the investor cannot observe adoption decisions or infer them from profit realizations since $\tilde{\pi}$ is sufficiently noisy.

The valuation of firms in the green disclosure category in equation (2) decreases with ϕ because more dirty firms adopting the green technology increases the proportion of low-type green firms in the green disclosure category, leading to a higher weight on their lower valuation.

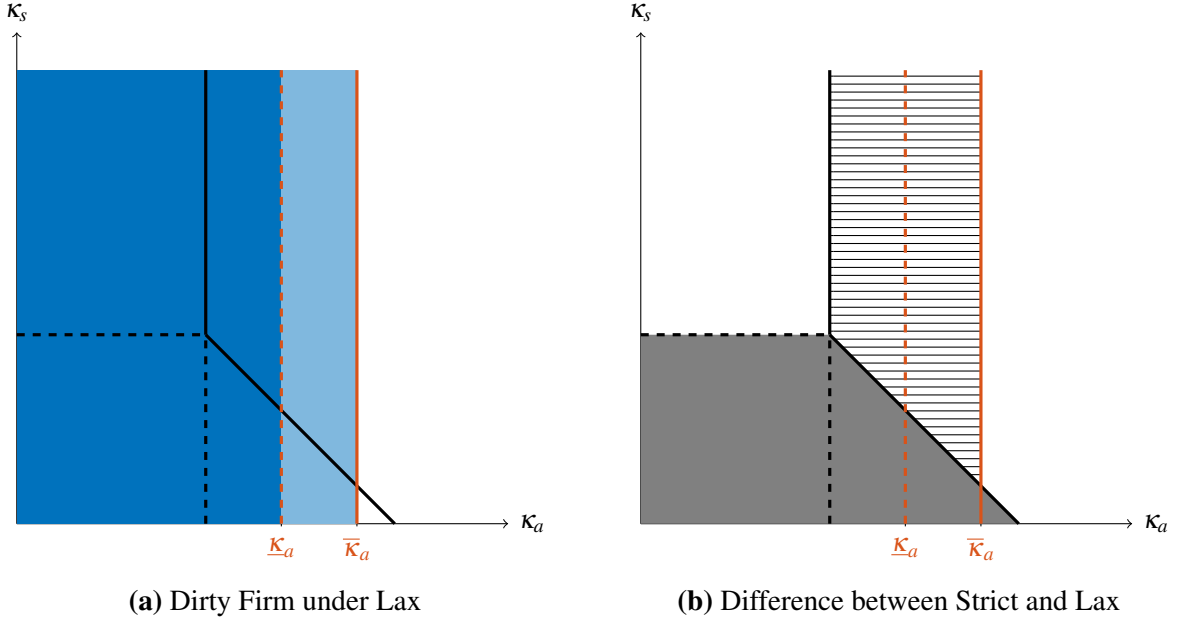
Proposition 1. *Under time-invariant lax green disclosure requirements, there exist two thresholds $\underline{\kappa}_a$ and $\overline{\kappa}_a$, where $\frac{\lambda\Delta_a}{1-\beta} < \underline{\kappa}_a < \overline{\kappa}_a < \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$, such that (i) if $\kappa_a \leq \underline{\kappa}_a$, all dirty firms adopt the green technology ($\phi = 1$); (ii) if $\kappa_a \in (\underline{\kappa}_a, \overline{\kappa}_a)$, a fraction of dirty firms adopt the green technology ($\phi \in (0, 1)$), which is decreasing in κ_a ; and (iii) if $\kappa_a \geq \overline{\kappa}_a$, no dirty firm adopts the green technology ($\phi = 0$).*

Proposition 1 shows that adoption decreases with its cost. If the adoption cost is sufficiently low, all dirty firms adopt the green technology; if it is sufficiently high, none adopt it. In the intermediate range of adoption costs, only a fraction of dirty firms adopt the green technology because adoption decisions are strategic substitutes—as more dirty firms adopt, the valuation of firms in the green disclosure category decreases, making further adoption less attractive.

The proposition also shows that lax green disclosure can increase adoption incentives compared to strict green disclosure. Under strict requirements, adoption alone being optimal requires $\frac{\lambda\Delta_a}{1-\beta} \geq \kappa_a$. Since $\frac{\lambda\Delta_a}{1-\beta} < \underline{\kappa}_a < \overline{\kappa}_a$, lax green disclosure provides stronger incentives for adoption alone. The key advantage is that adoption alone generates a higher valuation gain that incorporates both the direct valuation gain from becoming a low-type green firm and part of high-type green firms' higher valuation. Through this pooling, lax green disclosure increases adoption incentives by creating a mis-valuation subsidy.

In Figure 3a, the thresholds $\underline{\kappa}_a$ and $\overline{\kappa}_a$ illustrate how lax green disclosure alters adoption incen-

Figure 3: Adoption of the Green Technology by Dirty Firms under Time-invariant Lax Green Disclosure Requirements



Notes: Figure (a) plots dirty firms' adoption and scaling decisions under time-invariant lax green disclosure requirements. The thresholds in black are the same as in Figure 2. The dark-blue area represents the region of parameters for which all dirty firms adopt the green technology but do not scale it. The light-blue area represents the region of parameters for which a fraction of dirty firms adopt the green technology but do not scale it, where the fraction is decreasing in the adoption cost κ_a . Figure (b) highlights where the adoption and scaling decisions of initially dirty firms differ between strict and time-invariant lax green disclosure requirements. The area with lines represents the set of parameters for which lax green disclosure generates at least some adoption, whereas strict green disclosure generates neither adoption nor scaling. The gray area represents the set of parameters for which strict green disclosure generates adoption and scaling, whereas lax green disclosure generates some adoption at most.

tives relative to strict green disclosure. The figure shows three effects. First, lax green disclosure requirements can expand the range of adoption costs where adoption alone is optimal. Second, they eliminate scaling incentives by pooling high-type and low-type green firm valuations. Third, this elimination of scaling can reduce adoption incentives by removing the option value of future scaling. Figure 3b contrasts the strict and lax disclosure regimes, with the lined region showing where lax green disclosure generates at least some adoption while strict disclosure generates neither adoption nor scaling.

Under strict green disclosure requirements, the initial distribution of firm types does not affect firm valuations, and adoption and scaling decisions depend solely on the characteristics of the transition technology. Under lax green disclosure requirements, the distribution of high-type and low-type green firms affects the valuation of firms in the green disclosure category, thereby affect-

ing dirty firms' adoption decisions. Let $\alpha = \frac{\mu_{gH}}{\mu_{gH} + \mu_{gL}}$ denote the proportion of initially high-type green firms among initially green firms.

Corollary 2. *As the proportion of initially high-type green firms amongst initially green firms, α , increases, while keeping the proportion of initially dirty firms, μ_d , constant, more dirty firms adopt the green technology under lax green disclosure requirements, reflected in higher $\underline{\kappa}_a$, $\bar{\kappa}_a$, and ϕ .*

When the proportion of initially high-type green firms is higher, adoption provides a greater mis-valuation subsidy, leading more dirty firms to adopt. This reveals an interesting insight: The greater the number of genuinely green firms present when green disclosure requirements are introduced, the more valuable it becomes to obscure greenness levels to generate adoption incentives. This insight highlights that effective green disclosure requirements must consider not only firm-level transition technology but also the broader market equilibrium, including the distribution of firm types and how the presence of green firms influences dirty firms' adoption incentives.

5.2 Optimal Time-Invariant Green Disclosure Requirements

If the inequality in equation (1) holds, dirty firms adopt under strict green disclosure requirements. In this case, time-invariant lax green disclosure offers no advantage. Intuitively, while it may still generate adoption, it prevents scaling, whereas strict green disclosure allows for both. Thus, when strict green disclosure provides sufficient adoption incentives, time-invariant lax green disclosure adds no benefit while potentially imposing costs due to the lack of scaling.

Proposition 2. *If the inequality in equation (1) holds, the regulator prefers strict green disclosure requirements to time-invariant lax green disclosure requirements if $\kappa_s \leq \frac{\lambda \Delta_s}{1-\beta}$ and is indifferent between the two green disclosure requirements otherwise.*

Proposition 2 provides a necessary condition for lax green disclosure requirements to be optimal: the inequality in equation (1) must be violated, as otherwise strict green disclosure weakly dominates.

When this inequality is violated, dirty firms do not adopt under strict green disclosure requirements. Here, lax green disclosure may help overcome this roadblock and facilitate the green transition of dirty firms.

Proposition 3. *If the inequality in equation (1) is violated, the regulator prefers time-invariant lax green disclosure requirements to strict green disclosure requirements (i) if $\kappa_a < \bar{\kappa}_a$ and $\kappa_s > \frac{\lambda\Delta_s}{1-\beta}$, and (ii) if $\kappa_a < \bar{\kappa}_a$, $\kappa_s \leq \frac{\lambda\Delta_s}{1-\beta}$, and*

$$\phi\mu_d \left(\frac{\Delta_a}{1-\beta} - \kappa_a \right) > \mu_{gL} \left(\frac{\Delta_s}{1-\beta} - \kappa_s \right), \quad (3)$$

where $\bar{\kappa}_a$ and ϕ are given in Proposition 1. Otherwise, the regulator either prefers strict green disclosure requirements to time-invariant lax green disclosure requirements or is indifferent between the two green disclosure requirements.

Proposition 3 adds another necessary condition for time-invariant lax green disclosure to be optimal: $\kappa_a < \bar{\kappa}_a$. This condition ensures that lax green disclosure increases adoption relative to strict green disclosure. The parameters satisfying both necessary conditions correspond to the horizontally lined area in Figure 3b.

The proposition also provides sufficient conditions for time-invariant lax green disclosure requirements to be optimal. In case (i), scaling is too costly ($\kappa_s > \frac{\lambda\Delta_s}{1-\beta}$), and lax green disclosure increases the adoption incentives of initially dirty firms while not impacting the scaling efforts of initially low-type green firms. In case (ii), with lower scaling costs ($\kappa_s \leq \frac{\lambda\Delta_s}{1-\beta}$), lax green disclosure generates a trade-off: it reduces scaling but increases adoption. Equation (3) determines whether the social benefits outweigh the costs. The benefit from increased adoption by initially dirty firms, $\phi\mu_d \left(\frac{\Delta_a}{1-\beta} - \kappa_a \right)$, must exceed the cost of reduced scaling by initially low-type green firms, $\mu_{gL} \left(\frac{\Delta_s}{1-\beta} - \kappa_s \right)$.

An important insight is that optimal green disclosure requirements may involve intentional obfuscation and mis-valuation, which we refer to as government-mandated greenwashing. This concept of greenwashing differs from the standard notion of firms intentionally misrepresenting their level of greenness. This has significant empirical implications: Dirty firms may genuinely improve their level of greenness while appearing greener than they fundamentally are. Importantly, the ability to obfuscate can be crucial for incentivizing reform. This contrasts with studies interpreting evidence of greenwashing as indicating the absence of firms reforming (e.g., Dumitrescu et al., 2022; Duchin et al., 2025). Our analysis suggests firms may undertake genuine reform while also

appearing to engage in greenwashing.

6 Dynamic Green Disclosure Requirements

This section examines a dynamic approach that starts with lax green disclosure and gives the regulator the option to switch to strict green disclosure (i.e., $\rho > 0$). As shown in Section 5, a necessary condition for time-invariant lax green disclosure to dominate strict green disclosure is that there is no adoption under strict—that is, when condition (1) is violated. The same argument is true in the case of dynamic green disclosure. Therefore, we study dynamic green disclosure requirements only when inequality (1) is violated. In Section 6.1, we examine managers' adoption and scaling decisions. In Section 6.2, we study the regulator's optimal choice of green disclosure requirements.

6.1 Green Technology Adoption and Scaling

Assume the inequality in equation (1) is violated and consider dynamic green disclosure requirements that mandate lax green disclosure in period $t = 0$. With probability $\rho > 0$, the regulator can switch to strict green disclosure in subsequent periods.

As in Section 5.1, managers never scale under lax green disclosure.¹⁷ Once firms adopt the green technology in period $t = 0$, lax green disclosure provides no further benefit. However, scaling may occur under strict green disclosure. Specifically, as shown in Lemma 1, all low-type green firms scale the green technology under strict disclosure if and only if $\frac{\lambda\Delta_s}{1-\beta} \geq \kappa_s$.

Lemma 4. *Assume that the inequality in equation (1) is violated. Consider the regulator's decision to switch from lax to strict green disclosure if given the option to switch at the beginning of period $t > 0$. If $\frac{\lambda\Delta_s}{1-\beta} \geq \kappa_s$, the regulator prefers to implement strict green disclosure requirements. If $\frac{\lambda\Delta_s}{1-\beta} < \kappa_s$, the regulator is indifferent between keeping lax green disclosure requirements and switching to strict green disclosure requirements.*

¹⁷Note that the logic of the proof of Lemma 3 also applies to dynamic green disclosure requirements. In any equilibrium, the valuation of a low-type and a high-type green firm gross of potential adoption and scaling costs is identical if green disclosure requirements are lax. A manager, therefore, never scales the green technology under lax green disclosure requirements.

Since the regulator either prefers or is indifferent to switching to strict green disclosure, we can assume they always switch. Note that the same result would be obtained if the regulator could commit to a future switch when designing requirements at the beginning of period $t = 0$.

As with time-invariant lax green disclosure requirements, the investor's valuation of a firm in the green disclosure category at the end of period $t = 0$ depends on the fraction of dirty firms that adopt the green technology. However, under dynamic green disclosure requirements, the valuation also incorporates the option value of future scaling. Let $\phi^D \in [0, 1]$ denote the fraction of dirty firms adopting the green technology in period $t = 0$ under dynamic green disclosure. The expected end-of-period $t = 0$ valuation of a firm in the green disclosure category, excluding potential adoption costs, is

$$V = \pi + \theta_{gL} \lambda b_{gL} + \theta_{gH} \lambda b_{gH} + \beta \left(\rho \left(\frac{\pi}{1-\beta} + \theta_{gL} \max \left\{ \frac{\lambda b_{gH}}{1-\beta} - \kappa_s, \frac{\lambda b_{gL}}{1-\beta} \right\} + \theta_{gH} \frac{\lambda b_{gH}}{1-\beta} \right) + (1-\rho)V \right), \quad (4)$$

where $\theta_{gL} = \frac{\phi^D \mu_d + \mu_{gL}}{\phi^D \mu_d + \mu_{gL} + \mu_{gH}}$ and $\theta_{gH} = 1 - \theta_{gL} = \frac{\mu_{gH}}{\phi^D \mu_d + \mu_{gL} + \mu_{gH}}$. Terms with θ_{gH} capture the valuation components for high-type green firms, while terms with θ_{gL} represent the valuation components for low-type green firms, including their option to scale the green technology when disclosure requirements become strict.

The expected valuation in equation (4) net of the potential adoption cost can be written as

$$\underbrace{\frac{\pi + \theta_{gL} \lambda b_{gL} + \theta_{gH} \lambda b_{gH}}{1-\beta} - \kappa}_{\text{Valuation without scaling}} + \underbrace{\frac{\beta \rho}{1-\beta(1-\rho)} \theta_{gL} \max \left\{ \frac{\lambda \Delta_s}{1-\beta} - \kappa_s, 0 \right\}}_{\text{Valuation boost from scaling}}, \quad (5)$$

where $\kappa = \kappa_a$ for adopting firms and $\kappa = 0$ otherwise. A dirty firm adopts if this valuation with $\kappa = \kappa_a$ exceeds that of remaining a dirty firm, $\frac{\pi + \lambda b_d}{1-\beta}$.

When $\frac{\lambda \Delta_s}{1-\beta} < \kappa_s$, there is no scaling under strict green disclosure. The conditions for dirty firms' adoption of the green technology then match those under time-invariant lax green disclosure requirements, determined by thresholds $\underline{\kappa}_a$ and $\bar{\kappa}_a$ from Proposition 1. Intuitively, since no firm will scale the green technology in the future, the relative proportions of low-type and high-type green firms will stay constant over time, and the mis-valuation subsidy equals that under time-

invariant lax green disclosure requirements.

Corollary 3. *Consider dynamic green disclosure requirements and assume that the inequality in equation (1) is violated. If $\frac{\lambda\Delta_s}{1-\beta} < \kappa_s$, no low-type green firm scales the green technology when green disclosure requirements become strict and the adoption decisions of initially dirty firms in period $t = 0$ are as described in Proposition 1.*

When $\frac{\lambda\Delta_s}{1-\beta} \geq \kappa_s$, scaling occurs under strict green disclosure. Dirty firms that adopt the green technology in period $t = 0$ scale it once disclosure requirements become strict. Importantly, if the inequality is strict, the anticipation of scaling in the future increases a firm's valuation in the green disclosure category in period $t = 0$, boosting adoption incentives.

To understand why adoption incentives are higher under dynamic versus lax green disclosure, consider the valuation of a firm in the green disclosure category in equation (5) if we restrict the proportion of dirty firms that adopt the green technology to be the same as that in the time-invariant case represented in equation (1). Under time-invariant lax green disclosure, the proportions of low-type and high-type green firms remain constant over time. Under dynamic green disclosure, the proportion of high-type green firms will increase in the future. The faster the switch to strict green disclosure, the higher the expected valuation. Thus, valuations are strictly higher in the case of dynamic green disclosure, encouraging more dirty firms to adopt the green technology. Consequently, the expectation of strict green disclosure amplifies the effectiveness of lax green disclosure in overcoming roadblocks in the green transition.

Proposition 4. *Consider dynamic green disclosure requirements and assume that the inequality in equation (1) is violated and that $\frac{\lambda\Delta_s}{1-\beta} > \kappa_s$. There exist two thresholds $\underline{\kappa}_a^D$ and $\bar{\kappa}_a^D$ satisfying $\underline{\kappa}_a^D < \bar{\kappa}_a^D$, $\frac{\lambda\Delta_a}{1-\beta} < \underline{\kappa}_a < \underline{\kappa}_a^D$, and $\bar{\kappa}_a < \bar{\kappa}_a^D < \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$, where $\underline{\kappa}_a$ and $\bar{\kappa}_a$ are the adoption thresholds from Proposition 1, such that: (i) if $\kappa_a \leq \underline{\kappa}_a^D$, all dirty firms adopt the green technology ($\phi^D = 1$); (ii) if $\kappa_a \in (\underline{\kappa}_a^D, \bar{\kappa}_a^D)$, a fraction of dirty firms adopt the green technology ($\phi^D \in (0, 1)$), which is decreasing in κ_a ; and (iii) if $\kappa_a \geq \bar{\kappa}_a^D$, no dirty firm adopts the green technology ($\phi^D = 0$). The fraction of dirty firms that adopt the green technology under dynamic green disclosure requirements, ϕ^D , is (weakly) larger than under time-invariant lax green disclosure requirements, ϕ , and is (weakly) decreasing in κ_s . Further, all low-type green firms scale the green technology once green disclosure requirements become strict.*

This proposition shows that if scaling occurs in the future, dynamic green disclosure can increase both adoption and scaling compared to time-invariant lax green disclosure. The anticipated switch to strict green disclosure preserves the option value of scaling, which is lost under time-invariant lax green disclosure.

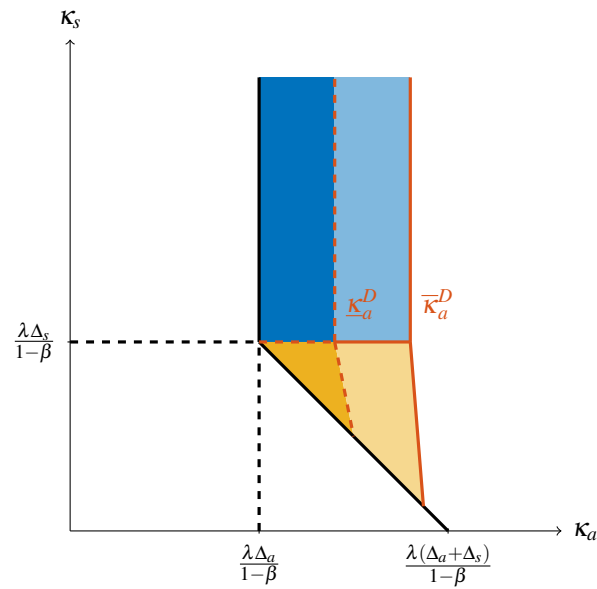
Figure 4 shows adoption and scaling decisions of initially dirty firms under dynamic green disclosure requirements when the inequality in equation (1) is violated. The blue regions match Figure 3a, as the adoption thresholds are identical when $\kappa_s > \frac{\lambda \Delta_s}{1-\beta}$. The dark-yellow area shows the region in which all firms adopt the green technology in period $t = 0$ and scale after the green disclosure requirements become strict. The light-yellow area shows the region in which a fraction of dirty firms adopt and later scale. Since inequality (1) is violated, no additional adoption occurs after requirements become strict. Note that the option value of scaling is discounted since strict green disclosure is implemented only with a given probability in each future period.

Dynamic green disclosure creates important interactions between disclosure requirements over time. Anticipating strict green disclosure in the future strengthens lax disclosure's effectiveness by preserving the option value of scaling. As such, lax requirements are more effective in promoting adoption if they are expected to be temporary rather than permanent. In addition, initial lax green disclosure enhances strict disclosure's impact by creating more firms that eventually scale the green technology. This interaction can generate more adoption and more scaling than either requirement alone. Denote by $\hat{\mu}_d$, $\hat{\mu}_{gL}$, and $\hat{\mu}_{gH}$ the long-run distribution of firm types after the switch to strict green disclosure under dynamic green disclosure requirements.

Corollary 4. *Assume that the inequality in equation (1) is violated. Consider the case in which dynamic green disclosure requirements interact over time: $\kappa_s < \frac{\lambda \Delta_s}{1-\beta}$ and $\kappa_a \leq \underline{\kappa}_a^D$, where $\underline{\kappa}_a^D$ is given in Proposition 4. Then, dynamic green disclosure requirements generate a complete green transition, $\hat{\mu}_d = 0$, $\hat{\mu}_{gL} = 0$, and $\hat{\mu}_{gH} = \mu_d + \mu_{gL} + \mu_{gH}$, whereas strict green disclosure only generates scaling, $\hat{\mu}_d = \mu_d$, $\hat{\mu}_{gL} = 0$, and $\hat{\mu}_{gH} = \mu_{gL} + \mu_{gH}$, and time-invariant lax green disclosure (i.e., $\rho = 0$) only generates at most some adoption, $\hat{\mu}_d \in [0, \mu_d]$, $\hat{\mu}_{gL} \in [\mu_{gL}, \mu_{gL} + \mu_d]$, and $\hat{\mu}_{gH} = \mu_{gH}$.*

Importantly, dynamic green disclosure facilitates greater adoption during the lax phase of requirements compared to time-invariant lax green disclosure and facilitates more scaling during the strict phase compared to time-invariant strict green disclosure. In other words, combining lax and

Figure 4: Adoption and Scaling of the Green Technology by Dirty Firms under Dynamic Green Disclosure Requirements



Notes: This figure plots dirty firms' adoption and scaling decisions under dynamic green disclosure requirements for the relevant cases in which the inequality in equation (1) is violated. The thresholds in black are the same as in Figure 2. The area in dark blue represents the region of parameters for which all dirty firms adopt the green technology but do not scale it. The light-blue area represents the region of parameters for which a fraction of dirty firms adopt the green technology but do not scale it, where the fraction is decreasing in the adoption cost κ_a . The dark-yellow area represents the region of parameters for which dirty firms adopt the green technology in period $t = 0$ and scale it once the green disclosure requirements become strict. The light-yellow area represents the region of parameters for which a fraction of dirty firms adopt the green technology and scale it in the future.

strict green disclosure generates a broader green transition than the sum of their individual effects. Greater adoption under dynamic green disclosure occurs because the anticipation of strict green disclosure requirements in the future preserves the option value of scaling and strengthens adoption incentives. Greater scaling under dynamic green disclosure occurs because increased adoption leads to a larger measure of low-type green firms that eventually scale the green technology.

The above corollary implies the regulator would not want to commit to time-invariant lax green disclosure requirements even if they could. Comparing Figures 3a and 4, adoption incentives are identical under both regimes in the blue region where $\kappa_s > \frac{\lambda\Delta_s}{1-\beta}$, as dirty firms do not anticipate scaling the green technology in the future after adoption. However, in the yellow region where $\kappa_s < \frac{\lambda\Delta_s}{1-\beta}$, dirty firms expect future scaling, strengthening adoption incentives through the option value of scaling. While time-invariant lax green disclosure eliminates scaling incentives, dynamic green disclosure requirements preserve them while increasing the incentive to adopt the green technology. Dynamic requirements, therefore, dominate time-invariant lax green disclosure requirements in this region.

Lemma 5. *Consider dynamic green disclosure requirements and assume that the inequality in equation (1) is violated and that $\frac{\lambda\Delta_s}{1-\beta} > \kappa_s$. Then $\underline{\kappa}_a^D$ and $\overline{\kappa}_a^D$ are increasing in ρ , and if $\phi^D \in (0, 1)$, then ϕ^D is increasing in ρ .*

Lemma 5 shows how the expected speed of switching to strict disclosure affects adoption incentives. A higher probability of switching increases dirty firms' adoption, reflected in higher thresholds $\underline{\kappa}_a^D$ and $\overline{\kappa}_a^D$, and a higher fraction of dirty firms that adopt the green technology, ϕ^D . Intuitively, increasing the expected speed of switching to strict disclosure increases the option value of scaling, strengthening initial adoption incentives. The ease of regulatory adjustment thus plays a crucial role in generating adoption incentives. In Section 6.2, we discuss the implications for the optimal choice of ρ if the regulator can influence ρ .

6.2 Optimal Green Disclosure Requirements

In this section, we compare dynamic and time-invariant strict green disclosure requirements. The comparison depends on the scaling cost κ_s . If $\kappa_s > \frac{\lambda\Delta_s}{1-\beta}$, there is no scaling under time-invariant

strict green disclosure, and dynamic green disclosure improves adoption incentives when $\kappa_a < \bar{\kappa}_a^D$. In this case, dynamic green disclosure requirements dominate. If $\kappa_s \leq \frac{\lambda \Delta_s}{1-\beta}$, initially low-type green firms scale faster under time-invariant strict green disclosure, creating a trade-off between generating adoption incentives for dirty firms and delaying scaling for initially low-type green firms.

Proposition 5. *If the inequality in equation (1) is violated, the regulator prefers dynamic green disclosure requirements to time-invariant strict green disclosure requirements (i) if $\kappa_a < \bar{\kappa}_a^D$ and $\kappa_s > \frac{\lambda \Delta_s}{1-\beta}$, and (ii) if $\kappa_a < \bar{\kappa}_a^D$, $\kappa_s \leq \frac{\lambda \Delta_s}{1-\beta}$, and*

$$\phi^D \mu_d \left(\frac{\Delta_a}{1-\beta} - \kappa_a + \frac{\beta \rho}{1-\beta(1-\rho)} \left(\frac{\Delta_s}{1-\beta} - \kappa_s \right) \right) > \mu_{gL} \frac{1-\beta}{1-\beta(1-\rho)} \left(\frac{\Delta_s}{1-\beta} - \kappa_s \right), \quad (6)$$

where ϕ^D is given in Proposition 4. Otherwise, the regulator either prefers time-invariant strict green disclosure requirements to dynamic green disclosure requirements or is indifferent between the two green disclosure requirements.

Proposition 5 identifies two cases where dynamic green disclosure is optimal. In case (i), there are no costs because dynamic green disclosure requirements do not delay scaling. In case (ii), even though low-type green firms scale the green technology after the disclosure requirements become strict, dynamic green disclosure delays scaling by initially low-type green firms. The optimality of dynamic green disclosure requirements requires that the social benefit of increased adoption and eventual scaling, $\phi^D \mu_d \left(\frac{\Delta_a}{1-\beta} - \kappa_a + \frac{\beta \rho}{1-\beta(1-\rho)} \left(\frac{\Delta_s}{1-\beta} - \kappa_s \right) \right)$, outweighs the social cost of delayed scaling by initially low-type green firms, $\mu_{gL} \frac{1-\beta}{1-\beta(1-\rho)} \left(\frac{\Delta_s}{1-\beta} - \kappa_s \right)$, as shown in equation (6). As such, the regulator faces a trade-off between slowing down the green transition of some firms and incentivizing the green transition of others, highlighting a novel trade-off between the pace and breadth of the green transition.

Our framework explains recent policy initiatives like the SFDR, which had less stringent disclosure from 2021 to 2023, followed by increased stringency. Our model suggests this dynamic approach may incentivize firms to undertake costly early-stage investments necessary for their green transition. Consistent with this, Emiris et al. (2024) and Spaans et al. (2024) find decreased emission intensity during SFDR's initial phase. Importantly, anticipated stricter requirements may

have strengthened early adoption incentives. As such, a time-invariant disclosure standard resembling only the SFDR's initial phase may be much less effective.

Lemma 6. *Assume that the inequality in equation (1) is violated and let $\kappa_s \leq \frac{\lambda \Delta_s}{1-\beta}$. If $\kappa_a < \bar{\kappa}_a^D$ and inequality (6) is satisfied for some $\rho = \bar{\rho}$ such that the regulator prefers dynamic green disclosure requirements to time-invariant strict green disclosure requirements, then the regulator prefers dynamic green disclosure requirements to time-invariant strict green disclosure requirements for all $\rho > \bar{\rho}$.*

In case (ii) of Proposition 5, both the costs and benefits of dynamic green disclosure requirements vary with ρ . A higher ρ increases the benefit by strengthening adoption incentives and reduces the cost by reducing the delay in scaling. Therefore, the regulatory inclination to impose these dynamic requirements increases in ρ .

The preceding analysis implies that the regulator may have an incentive to increase ρ .¹⁸ While ρ captures political opposition or legal and institutional constraints delaying regulatory changes, regulators may be able to increase ρ through careful design that is less susceptible to legal challenges or by engaging in strategic lobbying to mitigate opposition. With a convex cost function of increasing ρ , $c(\rho)$, we would be able to derive an optimal interior ρ .

7 Extensions and Robustness

This section explores extensions of the baseline model and demonstrates the robustness of our main results by studying a broader class of disclosure requirements. First, we introduce voluntary green disclosure, allowing some firms to reveal their level of greenness. Second, we add signals about firm types to capture learning from other information sources. We examine how these extensions affect the optimality of dynamic green disclosure requirements relative to strict green disclosure. As in Section 6, we only study the relevant cases in which the inequality (1) is violated. Third, we demonstrate the robustness of our main results by considering a broader class of disclosure requirements: those that pool dirty and low-type green firms and those that pool dirty and high-type green firms.

¹⁸In Section 8, we explore an additional consideration: when adoption decisions take time to implement, a lower ρ may be beneficial.

7.1 Voluntary Green Disclosure

In our baseline model, firms cannot privately signal their types to the investor, which may only be revealed through green disclosure requirements. Here, we introduce credible voluntary disclosure at a cost.

We extend the model by allowing some firms to reveal their type at the end of period $t = 0$ at cost $c \geq 0$. Each firm has access to this technology with probability $\psi \in (0, 1)$. We assume firms learn about whether they have access to the technology after adoption but before scaling decisions are made in period $t = 0$.¹⁹ With probability $1 - \psi$, a firm lacks access to the technology.

Voluntary green disclosure adds no value under strict green disclosure since firm types are already fully revealed. We thus focus on voluntary green disclosure decisions at the end of period $t = 0$ under initial lax green disclosure requirements. Note that “firm type” here refers to the firm’s status when endowed with the voluntary green disclosure technology before scaling occurs rather than its type at the end of the period.

With low enough voluntary disclosure costs, high-type green firms with access to the voluntary disclosure technology will reveal their types. This force reduces the mis-valuation subsidy by reducing the proportion of high-type green firms in the green disclosure category. We first characterize adoption when only high-type green firms disclose their types.

Proposition 6. *Consider dynamic green disclosure requirements. There exist two thresholds $\underline{c}$ and $\bar{c}$, where $\bar{c} > \underline{c} \geq 0$, such that an equilibrium in which only high-type green firms with the voluntary green disclosure technology disclose their type exists if $c \in [\underline{c}, \bar{c}]$. In this equilibrium, the fraction of dirty firms that adopt the green technology, $\hat{\phi}^D$, is (weakly) smaller than in the baseline model, with a strict difference for some κ_a .*

Proposition 6 characterizes an equilibrium in which high-type green firms use the voluntary green disclosure technology, but low-type green firms do not. As high-type green firms exit the green disclosure category through voluntary disclosure, the lower proportion of high-type green

¹⁹Our key result in this section that firms’ incentives to adopt the green technology under lax green disclosure reduce in the presence of a voluntary green disclosure technology is also true if we instead assume that firms can adopt the green technology after they know whether or not they have access to the voluntary green disclosure technology. Below, in Footnote 20, we describe how the equilibrium changes under this alternative assumption. Further, note that it does not matter whether the firm makes the scaling decision before or after the voluntary green disclosure decision.

firms in this category reduces the mis-valuation subsidy and weakens dirty firms' adoption incentives.

If disclosure costs are low enough, low-type green firms may also have an incentive to voluntarily disclose their type. Intuitively, if a low-type green firm has access to the voluntary green disclosure technology, it can disclose its type and scale the green technology, obtaining the valuation of a high-type green firm.

Proposition 7. *Consider dynamic green disclosure requirements. If $\frac{\lambda\Delta_s}{1-\beta} > \kappa_s$ and $\frac{\mu_{gL}}{\mu_{gL}+\mu_{gH}}$ is sufficiently high, there exists a threshold $\bar{c} > 0$ such that an equilibrium in which all high-type and low-type green firms with the voluntary green disclosure technology disclose their type exists if $c \leq \bar{c}$. In such an equilibrium, the fraction of dirty firms that adopt the green technology, $\hat{\phi}^D$, is (weakly) smaller than in the baseline model, with a strict difference for some κ_a .*

Proposition 7 shows that low-type green firms wanting to voluntarily disclose their type requires two conditions: scaling benefits must exceed costs, and the proportion of low-type green firms must be high enough to make the mis-valuation subsidy sufficiently small. Furthermore, dirty firms also have a lower incentive to adopt the green technology under the initial lax green disclosure requirements when low-type green firms also disclose their type. The reason that disclosure by low-type green firms reduces adoption incentives is somewhat subtle. It arises due to a commitment problem that makes dirty firms not get the mis-valuation subsidy if they get access to the voluntary green disclosure technology after adopting the green technology, as they will also scale the green technology and eventually be revealed as a high-type green firm. Since inequality (1) is violated, dirty firms would not adopt if they knew with certainty that their type would be revealed.²⁰ Thus, voluntary green disclosure reduces adoption incentives of dirty firms as firms anticipate losing the mis-valuation subsidy with probability ψ .

While voluntary green disclosure reduces adoption incentives, it can accelerate scaling by low-type green firms under dynamic green disclosure. This creates a trade-off: reduced adoption incentives of dirty firms reduce the benefits of dynamic green disclosure, while earlier scaling by some low-type green firms reduces its costs. As such, increased transparency due to voluntary green

²⁰If we instead assumed that dirty firms make adoption decisions after they know if they have access to the voluntary green disclosure technology, the commitment problem would cause firms with this technology to decide not to adopt the green technology.

disclosure can reduce the breadth but increase the speed of the green transition. The regulator considers these competing effects when choosing green disclosure requirements.

Proposition 8. *If the inequality in equation (1) is violated, the regulator prefers dynamic green disclosure requirements to time-invariant strict green disclosure requirements (i) if a positive fraction of dirty firms adopt the green technology under dynamic green disclosure requirements and $\kappa_s > \frac{\lambda\Delta_s}{1-\beta}$, and (ii) if a positive fraction of dirty firms adopt the green technology under dynamic green disclosure requirements, $\kappa_s \leq \frac{\lambda\Delta_s}{1-\beta}$, and*

$$\hat{\phi}^D \mu_d \left(\frac{\Delta_a}{1-\beta} - \kappa_a + \frac{\beta\rho}{1-\beta(1-\rho)} \left(\frac{\Delta_s}{1-\beta} - \kappa_s \right) \right) > \mu_{gL} \frac{1-\beta}{1-\beta(1-\rho)} \left(\frac{\Delta_s}{1-\beta} - \kappa_s \right)$$

in the case of Proposition 6, where $\hat{\phi}^D$ is given in Proposition 6, and

$$\begin{aligned} \hat{\phi}^D \mu_d \left(\frac{\Delta_a}{1-\beta} - \kappa_a + \left(\psi + \frac{\beta\rho}{1-\beta(1-\rho)} (1-\psi) \right) \left(\frac{\Delta_s}{1-\beta} - \kappa_s \right) \right) > \\ (1-\psi) \mu_{gL} \frac{1-\beta}{1-\beta(1-\rho)} \left(\frac{\Delta_s}{1-\beta} - \kappa_s \right) \end{aligned}$$

in the case of Proposition 7, where $\hat{\phi}^D$ is given in Proposition 7. Otherwise, the regulator either prefers time-invariant strict green disclosure requirements to dynamic green disclosure requirements or is indifferent between the two green disclosure requirements.

While voluntary green disclosure reduces initial adoption incentives, it can provide benefits. If low-type green firms with access to voluntary green disclosure disclose their types and scale, this speeds up the green transition. For instance, with sufficiently low κ_a such that $\hat{\phi}^D = 1$ even if κ_a increases locally, increasing ψ can increase the speed without sacrificing the breadth of the green transition.

7.2 Signals of Firms' Types

Our baseline model assumes that the investor cannot infer a firm's type from financial information. In this section, we allow the investor to partially learn about firm types by assuming that each firm generates a fully revealing signal about its type with probability $\xi \in (0, 1)$ at the end of period

$t = 0$. We assume that firms learn whether their type will be revealed after adoption but before scaling decisions are made.²¹ As with voluntary green disclosure, the signals do not affect strict green disclosure. We thus focus on their impact during the initial lax period under dynamic green disclosure requirements.

Proposition 9. *Consider dynamic green disclosure requirements. Introducing a signal that reveals a firm's type with probability ξ (weakly) reduces the fraction of dirty firms that adopt the green technology, with a strict difference for some κ_a . The fraction of dirty firms that adopt the green technology, $\hat{\phi}^D$, is (weakly) decreasing in ξ and strictly decreasing in ξ for some κ_a .*

The impact of the signals depends on whether low-type green firms whose type is revealed scale the green technology. When $\kappa_s > \frac{\lambda\Delta_s}{1-\beta}$, low-type green firms never scale under any information environment. A dirty firm knows that if it adopts the green technology, then with probability ξ , it will be revealed as low-type green, losing the mis-valuation subsidy from being pooled with high-type green firms in the green disclosure category. This reduces the firm's adoption incentives under the initial lax green disclosure. When $\kappa_s \leq \frac{\lambda\Delta_s}{1-\beta}$, a low-type green firm whose type is revealed scales the green technology, but adoption incentives still decrease because firms lose the mis-valuation subsidy with probability ξ . Since inequality (1) is violated, dirty firms would not adopt the green technology if they knew with certainty that their type would be revealed.

While signals always reduce adoption incentives, they can speed up scaling by low-type green firms under dynamic green disclosure requirements. The regulator accounts for these additional costs and benefits when choosing requirements.

Proposition 10. *If the inequality in equation (1) is violated, the regulator prefers dynamic green disclosure requirements to time-invariant strict green disclosure requirements (i) if a positive fraction of dirty firms adopt the green technology under dynamic green disclosure requirements and $\kappa_s > \frac{\lambda\Delta_s}{1-\beta}$, and (ii) if a positive fraction of dirty firms adopt the green technology under dynamic*

²¹As in the extension studying voluntary green disclosure in Section 7.1, our key result in this section that firm incentives to adopt the green technology are weaker in the presence of a signal that reveals firm types is also true if we instead assume that adoption decisions happen after the signal realization.

green disclosure requirements, $\kappa_s \leq \frac{\lambda \Delta_s}{1-\beta}$, and

$$\hat{\phi}^D \mu_d \left(\frac{\Delta_a}{1-\beta} - \kappa_a + \left(\xi + \frac{\beta \rho}{1-\beta(1-\rho)} (1-\xi) \right) \left(\frac{\Delta_s}{1-\beta} - \kappa_s \right) \right) > (1-\xi) \mu_{gL} \frac{1-\beta}{1-\beta(1-\rho)} \left(\frac{\Delta_s}{1-\beta} - \kappa_s \right),$$

where $\hat{\phi}^D$ is given in Proposition 9. Otherwise, the regulator either prefers time-invariant strict green disclosure requirements to dynamic green disclosure requirements or is indifferent between the two green disclosure requirements.

With κ_a sufficiently low, maintaining that $\hat{\phi}^D = 1$ locally, increasing ξ can improve welfare by reducing the cost of dynamic green disclosure as more low-type green firms scale the green technology already in period $t = 0$. However, in general, a higher probability of firm types being revealed creates a trade-off: lowering the cost of dynamic green disclosure requirements by speeding up scaling versus lowering its benefit through reducing adoption. Increased transparency through independent signals about firm types may, therefore, reduce the breadth of the green transition while increasing its speed.

7.3 Alternative Green Disclosure Requirements

Our model features two possible green disclosure requirements: strict disclosure revealing all firm types and lax disclosure pooling two of the three firm types. While our baseline model focused on lax disclosure that pools high-type and low-type green firms, reflecting real-world implementations, this section demonstrates our results' robustness by examining the remaining alternatives: pooling dirty with low-type green firms and pooling dirty with high-type green firms. Note that because revealed information cannot be reversed, we do not consider switches from one type of lax disclosure to another when considering dynamic green disclosure requirements.

In Section 7.3.1, we examine lax green disclosure requirements that pool dirty and high-type green firms and demonstrate that they are never optimal. Section 7.3.2 studies requirements that pool dirty and low-type green firms and demonstrates the robustness of our central finding that dynamic requirements initially pooling low-type and high-type green firms are optimal when adoption

is the transition roadblock. Additionally, we show that when scaling—not adoption—creates the roadblock, pooling dirty with low-type green firms can become optimal by strengthening scaling incentives. To distinguish between adoption and scaling roadblocks, we focus on two cases: When $\kappa_s \leq \frac{\lambda \Delta_s}{1-\beta}$, this represents situations where adoption, but not scaling, can be the roadblock. When $\kappa_a \leq \frac{\lambda \Delta_s}{1-\beta}$, this represents situations where scaling, but not adoption, can be the roadblock.²²

7.3.1 Pooling Dirty and High-Type Green Firms

We first establish that pooling dirty and high-type green firms is never optimal, both in the time-invariant (i.e., $\rho = 0$) and the dynamic (i.e., $\rho > 0$) case.

Proposition 11. *Green disclosure requirements that initially pool dirty and high-type green firms can never be optimal.*

Intuitively, such pooling reduces both scaling and adoption incentives. Low-type green firms face diminished incentives to scale because the valuation gain of becoming a high-type green firm is smaller than under strict disclosure. Meanwhile, dirty firms have weaker adoption incentives because they already enjoy higher valuations when pooled with high-type green firms than when their type is revealed to be dirty, reducing the gain from becoming low-type green.

7.3.2 Pooling Dirty and Low-Type Green Firms

Next, we analyze both time-invariant (i.e., $\rho = 0$) and dynamic (i.e., $\rho > 0$) lax green disclosure requirements that pool dirty and low-type green firms. For brevity, we refer to these as “time-invariant pooling at the bottom” and “dynamic pooling at the bottom,” respectively. We also refer to lax green disclosure requirements from our baseline model as “pooling at the top.”

Time-Invariant Pooling at the Bottom. Under time-invariant pooling at the bottom (i.e., $\rho = 0$), a firm’s valuation in the pooled disclosure category is a weighted average of dirty and low-type green valuations, with weights determined by their proportions. Note that dirty firms never adopt without additional scaling since adoption alone incurs costs without valuation benefits.

²²In the proofs in Appendix C, we additionally cover the case in which both adoption and scaling can jointly be roadblocks, that is, $\kappa_s > \frac{\lambda \Delta_s}{1-\beta}$ and $\kappa_a > \frac{\lambda \Delta_s}{1-\beta}$. The results are a straightforward extension of the two cases we analyze in the main text.

Lemma 7. *Under time-invariant pooling at the bottom, dirty firms never adopt without additional scaling the green technology.*

Let $\phi_{a,s} \in [0, 1]$ represent the fraction of dirty firms that adopt and scale in period $t = 0$, and $\phi_s \in [0, 1]$ represent the fraction of initially low-type green firms that scale in period $t = 0$. When $\phi_{a,s} < 1$ or $\phi_s < 1$, the investor's valuation of a firm in the pooled category is:

$$\frac{\pi + \frac{(1-\phi_{a,s})\mu_d}{(1-\phi_{a,s})\mu_d + (1-\phi_s)\mu_{gL}} \lambda b_d + \frac{(1-\phi_s)\mu_{gL}}{(1-\phi_{a,s})\mu_d + (1-\phi_s)\mu_{gL}} \lambda b_{gL}}{1 - \beta} = \frac{\pi + \lambda b_d + \frac{(1-\phi_s)\mu_{gL}}{(1-\phi_{a,s})\mu_d + (1-\phi_s)\mu_{gL}} \lambda \Delta_a}{1 - \beta}.$$

When $\phi_{a,s} = \phi_s = 1$, we assume the off-equilibrium valuation equals that of a dirty firm, as dirty firms have the strongest incentive to deviate. Unlike with pooling at the top, multiple equilibria can arise in the case of pooling at the bottom due to strategic complementarities in scaling decisions—as more low-type green firms scale, the valuation of firms in the pooled category decreases, and consequently, the valuation gain from scaling increases. We focus on welfare-maximizing equilibria.

Proposition 12. *Consider time-invariant pooling at the bottom.*

1. If $\kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta}$, the unique equilibrium has $\phi_{a,s} = \phi_s = 0$ (no adoption or scaling).
2. If $\kappa_s \leq \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta}$ and $\kappa_s + \kappa_a \leq \frac{\lambda(\Delta_s + \Delta_a)}{1 - \beta}$, there exists a welfare-maximizing equilibrium with $\phi_{a,s} = \phi_s = 1$ (full adoption and scaling).
3. If $\kappa_s \leq \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta}$ and $\kappa_a + \kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta}$, there exists a welfare-maximizing equilibrium with $\phi_{a,s} = 0$ and $\phi_s = 1$ (scaling without adoption).

Pooling at the bottom can enhance scaling incentives because low-type green firms are effectively taxed for not scaling by being pooled with dirty firms.

We now turn to the optimality of disclosure requirements. Compared to our baseline model, time-invariant pooling at the bottom is weakly dominated when either scaling is not a roadblock, that is, $\kappa_s \leq \frac{\lambda\Delta_s}{1 - \beta}$, or scaling costs are prohibitively high, that is, $\kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta}$.

Lemma 8. *When $\kappa_s \leq \frac{\lambda\Delta_s}{1 - \beta}$ or $\kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta}$, time-invariant pooling at the bottom never dominates strict disclosure or time-invariant pooling at the top.*

Intuitively, pooling at the bottom enhances scaling incentives but provides no advantage when scaling already occurs under full transparency or when scaling costs are prohibitively high. Consequently, our baseline model results are robust to introducing the complete set of disclosure requirements when adoption rather than scaling may constitute the transition roadblock (i.e., when $\kappa_s \leq \frac{\lambda \Delta_s}{1-\beta}$).

Next, we consider the case where scaling rather than adoption may constitute the transition roadblock (i.e., when $\kappa_a \leq \frac{\lambda \Delta_a}{1-\beta}$). In this scenario, when pooling at the bottom generates more scaling than full disclosure allows, the regulator may optimally choose to pool dirty with low-type green firms.

Proposition 13. *When $\frac{\lambda \Delta_s}{1-\beta} < \kappa_s \leq \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$ and $\kappa_a < \frac{\lambda \Delta_a}{1-\beta}$, there are two cases:*

1. *When $\kappa_a + \kappa_s \leq \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$, then time-invariant pooling at the bottom implements first-best and therefore dominates all green disclosure requirements from the baseline model.*
2. *When $\kappa_a + \kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$, then time-invariant pooling at the bottom may be optimal if the social value of the scaling it generates dominates the social value of adoption generated by either strict green disclosure requirements or time-invariant pooling at the top.*

Dynamic Pooling at the Bottom. To begin the analysis on dynamic pooling at the bottom (i.e., $\rho > 0$), we establish a similar result to Lemma 8, showing that our baseline model results are robust to introducing the complete set of disclosure requirements when adoption rather than scaling may constitute the transition roadblock (i.e., when $\kappa_s \leq \frac{\lambda \Delta_s}{1-\beta}$).

Lemma 9. *When $\kappa_s \leq \frac{\lambda \Delta_s}{1-\beta}$ or $\kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$, dynamic pooling at the bottom never dominates strict disclosure or dynamic pooling at the top.*

Next, we characterize firm decisions and regulatory switching choices for the remaining cases with dynamic pooling at the bottom. Notably, unlike with pooling at the top, regulatory commitment matters with pooling at the bottom. The expectation that the regulator will switch to strict disclosure in the future to induce adoption increases valuations in the pooled category, which paradoxically reduces scaling incentives. This contrasts with pooling at the top, where switching to induce scaling increases valuations and strengthens adoption incentives. The difference

stems from pooling at the bottom creating a tax for not scaling while pooling at the top creates an adoption subsidy. Higher valuations in the pooled category weaken this tax while enhancing the subsidy. Consequently, with pooling at the bottom, commitment to not switching might sometimes be optimal to maintain the effective tax on not scaling.

Proposition 14. *Consider dynamic pooling at the bottom when $\frac{\lambda\Delta_s}{1-\beta} < \kappa_s \leq \frac{\lambda(\Delta_a+\Delta_s)}{1-\beta}$ and $\kappa_a < \frac{\lambda\Delta_a}{1-\beta}$.*

1. *If $\kappa_s + \kappa_a \leq \frac{\lambda(\Delta_s+\Delta_a)}{1-\beta}$, there exists a welfare-maximizing equilibrium with $\phi_{a,s} = \phi_s = 1$ (full adoption and scaling), and the regulator does not switch to strict green disclosure.*
2. *If $\kappa_s + \kappa_a > \frac{\lambda(\Delta_s+\Delta_a)}{1-\beta}$, there exists a welfare-maximizing equilibrium with $\phi_{a,s} = 0$ and $\phi_s \geq 0$ (potentially some scaling without adoption) in period $t = 0$, the regulator switches to strict green disclosure, after which all dirty firms adopt but do not scale.*

Having characterized firm decisions and regulatory switching, we now examine optimal green disclosure requirements.²³ As in the time-invariant case, when scaling rather than adoption constitutes the transition roadblock (i.e., when $\kappa_a \leq \frac{\lambda\Delta_a}{1-\beta}$), the regulator may optimally pool dirty with low-type green firms.

Proposition 15. *When $\frac{\lambda\Delta_s}{1-\beta} < \kappa_s \leq \frac{\lambda(\Delta_a+\Delta_s)}{1-\beta}$ and $\kappa_a < \frac{\lambda\Delta_a}{1-\beta}$, there are two cases:*

1. *If $\kappa_s + \kappa_a \leq \frac{\lambda(\Delta_s+\Delta_a)}{1-\beta}$, then dynamic pooling at the bottom implements first-best and therefore dominates all green disclosure requirements from the baseline model.*
2. *If $\kappa_s + \kappa_a > \frac{\lambda(\Delta_s+\Delta_a)}{1-\beta}$, then dynamic pooling at the bottom may be optimal if the social value of the scaling it generates dominates the social value of adoption generated by strict green disclosure and dynamic pooling at the top.*

8 Discussion

In this section, we discuss some of our key assumptions and additional insights the model can generate.

²³In Section 6, we studied dynamic pooling at the top in cases where the inequality in equation (1) is violated. Note that when the inequality is satisfied and $\kappa_s \geq \frac{\lambda\Delta_s}{1-\beta}$, dynamic pooling at the top can at most implement adoption just as strict green disclosure does.

Microfoundations for Investor’s Utility from Social Benefit: As we emphasize in Section 3, we are agnostic about why the representative investor values greener firms more. The crucial feature of our framework is that firm valuations increase with the firm’s greenness under full information. There are multiple ways to microfound the representative investor’s preference for green firms, λ .

First, λ may capture that investors inherently care about externalities firms impose. The investor can either have deontological warm-glow preferences in which they inherently value firms for being green as in Heinkel et al. (2001), Pastor et al. (2021), and Pedersen et al. (2021), or consequentialist impact preferences which lead them to adopt an investment mandate with a commitment to pay a greenium as in Gupta et al. (2025). There is growing empirical evidence that moral and ethical considerations influence investors’ decision-making in a financial market context (e.g., Riedl and Smeets, 2017; Bauer et al., 2021; Humphrey et al., 2021; Zhang, 2021; Baker et al., 2022; Zhang, 2022; Bonnefon et al., 2022; Heeb et al., 2022; Giglio et al., 2025).²⁴

Second, λ can also capture investors’ concerns about physical or transition risks (e.g., Bolton and Kacperczyk, 2021b, 2022; Ilhan et al., 2023), consistent with the stated goal of some disclosure requirements to provide climate risk information (e.g., Carattini et al., 2022). Under such an interpretation, firms’ adoption and scaling decisions may represent measures to reduce their climate risk exposure. When $\lambda < 1$, investors focus narrowly on how such measures affect firm valuations, while the social planner cares more broadly about the societal value of the green transition, for example, how a reduction in firm emissions may reduce flood risk for households.

A third interpretation is that λ can capture additional financial profits that accrue to the firm from pro-social consumers, who have a higher willingness to pay for green products and services. Firms that are disclosed to be greener will attract more pro-social consumers. Under this interpretation, the additional profits that accrue to firms depend on the disclosure regulation as consumers base their purchasing decisions on their information set. As such, when firms are pooled into a single category, all firms in that category experience the same increase in profits (captured by λ times the expected social benefit) from pro-social consumer behavior.

Risky Option of Scaling: Our analysis highlights that the option value of scaling can motivate

²⁴See Kräussl et al. (2023) for a survey on the evidence for pro-social preferences in financial markets. For evidence on pro-social preferences in other non-financial contexts, see List (2009).

firms to adopt the green technology. If the option to scale is risky, firms may adopt it more readily because volatility increases the value of the real option to scale. For instance, if a dirty firm is considering adoption, uncertainty in scaling costs could strengthen adoption incentives. Thus, better information about the scaling technology might not necessarily lead to stronger adoption incentives if it reduces volatility.

Initial Distribution of Types: We assume an initial distribution of firm types with a positive mass of all three firm types. This raises the question: Why do low- and high-type green firms exist before green disclosure requirements are implemented? The practical answer is that this reflected reality when regulators began considering green disclosure requirements as a policy tool. Several factors may lead firms to improve greenness even without observable benefits for stakeholders. For example, as we discuss further below, this may reflect the preferences of corporate insiders such as managers, who would be willing to invest in green technology even if external stakeholders such as investors do not observe firms' greenness. Interestingly, if managers' pro-social preferences determine the initial distribution of firms, dirtier firms may have less pro-social managers and face even more substantial roadblocks in the green transition. Alternatively, investment decisions may generate different levels of greenness as by-products of technology shocks.

Pro-social Managers: While the sustainable finance literature focuses on investor preferences, managers may also have pro-social preferences (e.g., Guenzel et al., 2023). Introducing such preferences would strengthen incentives to adopt and scale the green technology. For example, denoting a manager's pro-social preferences by $\gamma > 0$, the manager's utility of an initially low-type green firm that scales the green technology would be the sum of the investor's valuation and the manager's non-pecuniary utility:

$$\frac{\pi + \lambda b_{gH}}{1 - \beta} - \kappa_s + \frac{\gamma b_{gH}}{1 - \beta}.$$

Thus, the manager of a low-type green firm would scale the green technology under full transparency if

$$\frac{(\lambda + \gamma)\Delta_s}{1 - \beta} \geq \kappa_s.$$

Under full transparency, managers' pro-social preferences are equivalent to investor's pro-social

preferences. In contrast, under lax green disclosure, they have different implications since the manager knows the firm's type, whereas the investor may not. For example, a pro-social manager of a low-type green firm may scale the green technology even under lax green disclosure, increasing the proportion of high-type green firms and, consequently, the mis-valuation subsidy. Adding pro-social managers would not change our core insights about the value of obfuscating firms' greenness to generate stronger incentives to adopt the green technology.

Managers' Objective Function: We assume that managers maximize the expected end-of-period firm valuations. Alternatively, they could care about both the current valuation and future changes they are privately informed about. For time-invariant green disclosure requirements, these assumptions are equivalent since valuations do not change after the first period.

However, under dynamic green disclosure requirements, these assumptions can cause subtle differences in the manager's optimization. As shown in Section 6, when $\kappa_s > \frac{\lambda \Delta_s}{1-\beta}$ and no scaling occurs, the expected end-of-period $t = 0$ valuation of low-type green firms is the same under dynamic and time-invariant lax green disclosure requirements. However, with dynamic green disclosure, these firms face a future drop in valuation, privately known to the manager, when requirements switch to strict. If managers care about these drops, dynamic green disclosure requirements become less effective in incentivizing adoption compared with time-invariant lax green disclosure requirements when $\kappa_s > \frac{\lambda \Delta_s}{1-\beta}$.

Additionally, when $\kappa_s < \frac{\lambda \Delta_s}{1-\beta}$, managers of a low-type green firm know that they will pay the scaling cost κ_s in the future, while investors only assign a probability based on the fraction of low-type green firms in the green disclosure category. If the manager cares about future valuation changes, this would also reduce adoption incentives. However, while this force may reduce the effectiveness of dynamic green disclosure requirements in incentivizing adoption, the qualitative result that these requirements can be optimal in overcoming roadblocks in the green transition continues to hold.

Historical Green Disclosure: In our model, since types are disclosed at the end of each period, there is no disclosure at the beginning of period $t = 0$. This implies that firms can take an action (adoption or scaling) before their type is disclosed. If allowed to set disclosure requirements at the beginning of period $t = 0$, the regulator can choose no disclosure at that time to replicate the

disclosure requirements we study.

Restricting attention to no disclosure of initial firm types at the beginning of period $t = 0$ is without loss of generality as the regulator always weakly prefers no initial disclosure. Under strict green disclosure, firm-type disclosure at the end of each period is sufficient for full transparency—the regulator need not require additional disclosure of the history of firm types or transition costs. While such additional disclosure would expand the investor’s information set, it would not affect firm valuations or managers’ decisions. Specifically, when the investor does not observe histories or transition costs, they cannot determine whether a current low-type green firm was previously dirty or whether a current high-type green firm was previously low-type green. The noisy profit $\tilde{\pi}$ prevents inference about transition costs κ from realizations of $\tilde{\pi} - \kappa$. Although the investor cannot observe the incurred transition costs, these costs reduce the net profit and, in turn, lower the expected end-of-period valuation. Thus, the manager always takes transition costs into account when making adoption and scaling decisions.

While historical disclosure does not matter under strict green disclosure requirements, this information must remain undisclosed under lax green disclosure to prevent identifying initially dirty firms that adopt the green technology as low-type green, preventing pooling with high-type green firms. The lack of credible historical information about firm greenness through other sources—for example, public news or voluntary disclosure—seems to be true in practice, as regulators cite a lack of historical data and a significant degree of information asymmetry regarding the greenness of firms as reasons for why regulatory intervention on disclosure is required in financial markets. Note that realized firm profits are public knowledge in our setting, and as such, the model has full financial disclosure.

This discussion highlights that effective green disclosure design must consider not only whether to require disclosure of current environmental performance but also whether to mandate disclosure of green investments and historical environmental performance. Indeed, Emiriz et al. (2024) find SFDR’s initial lax stage was more effective for funds without prior sustainability ratings, demonstrating how lax disclosure requirements can be more effective when historical information is limited.

Fairness, Political Economy, and Additional Costs: Limited transparency can appear unfair

by penalizing high-type green firms. The regulator effectively uses investor preferences to facilitate the green transition, imposing costs on green portfolio investors. This issue connects to a deeper question in the literature of whether green investors are consequentialist or deontological. As discussed in the model, investor preferences can reflect deontological warm-glow preferences (e.g., Heinkel et al., 2001; Pastor et al., 2021; Pedersen et al., 2021) or consequentialist broad-impact preferences which lead them to adopt an investment mandate with a commitment to pay a greenium (Gupta et al., 2025). Consequentialist investors might support lax green disclosure requirements because they value the green transition, while those with warm glow preferences might view it as unfair. In the latter case, if policy is determined by a political vote, the regulator may not be able to get support for optimal disclosure requirements.

Moreover, in our framework, there are no real benefits from reducing the cost of capital for high-type green firms. If high-type green firms could further innovate or further scale the green technology, lax green disclosure would create additional costs by delaying such investments until strict green disclosure is implemented. The regulator would need to consider these costs when designing green disclosure requirements.

Application to Carbon Taxes: Our results have important implications for carbon taxation. As discussed in Section 3, the parameter λ can represent various pricing factors, including investors' green preferences, exposure to physical and transition risks, and carbon taxes. Under full transparency, λ is equivalent to a carbon tax, with $\lambda = 1$ being a Pigouvian tax, inducing firms to fully internalize externalities and achieve first-best outcomes. However, as argued in Section 3, multiple forces constrain the implementation of a Pigouvian tax, resulting in a world where $\lambda < 1$.

When only suboptimal carbon taxes are feasible, our model suggests regulators may optimally complement them with disclosure regulation. As shown in Section 6, they may optimally implement dynamic green disclosure requirements that become more stringent over time. Under the carbon tax interpretation, this means initially obfuscating the tax base—the firm's type. Consequently, low-type green firms will pay a lower carbon tax under lax green disclosure compared to what they would pay under full transparency. This finding gives rise to an important insight: disclosure regulation that determines emissions measurement and disclosure may serve as a crucial complement to constrained carbon taxation, creating dynamic incentives to undertake the green

transition when optimal Pigouvian taxation is not feasible.

Time to Build: In Section 6, we demonstrate that an earlier shift to strict green disclosure enhances the effectiveness of dynamic green disclosure requirements, potentially incentivizing the regulator to increase ρ . This insight relies on the assumption that adoption decisions are implemented without delay. To illustrate the implications of relaxing this assumption, consider a scenario where adoption decisions made at $t = 0$ take $T > 1$ periods to materialize. Here, an early switch to strict green disclosure may reduce adoption incentives because firms anticipate being revealed as a low-type green firm upon adoption, forfeiting part of the mis-valuation subsidy available under lax green disclosure. Consequently, the regulator may prefer delaying the switch to strict green disclosure requirements.

This observation reveals a potential temporal trade-off in the design of dynamic green disclosure requirements. While an earlier shift to strict green disclosure can increase the expected discounted option value of scaling, it may weaken adoption incentives if adoption takes time to materialize.

Firm Entry and New Technologies: Our model reveals an important consideration regarding firm entry. Once strict green disclosure is implemented, and the inequality in equation (1) is violated, new dirty firms will never adopt the green technology. This suggests that green disclosure requirements should vary with firm age to encourage adoption among new entrants. Consider a scenario where a new measure of firms comprising all three types enters the market. Dynamic green disclosure requirements should optimally start with lax green disclosure for these firms' initial period in the market, providing necessary incentives to invest in green technology early in their lifecycle. This idea aligns with the empirical observation that green disclosure requirements often vary with firm characteristics such as size.

Reversible Transition Technology: In our baseline model, we assume that investments in the green transition are irreversible. This assumption is reasonable because resources invested in green innovation may be hard to recover, particularly for high fixed costs. Nevertheless, some investments may be partially reversible. For example, hiring specialized labor to scale a firm's green technology may be reversed by reducing the workforce. In our model, reversibility particularly matters for scaling because high-type green firms may want to reverse scaling when pooled with

low-type green firms.

If some high-type green firms can reverse the scaling of the green technology and recoup some of the scaling costs, they may do so during the lax period of dynamic green disclosure requirements because investors cannot detect the reversal. Under strict green disclosure, investors would immediately notice a scaling reversal and reduce the firm’s valuation accordingly. If high-type green firms with the reversal option do reverse under dynamic green disclosure, it would reduce dirty firms’ adoption incentives by decreasing the proportion of high-type green firms in the green disclosure category, lowering the mis-valuation subsidy. While this may reduce the regulator’s incentive to introduce dynamic green disclosure, the qualitative result about their optimality in addressing roadblocks in the green transition holds as long as not all high-type green firms will fully reverse scaling.

9 Conclusion

Given the urgency of the climate crisis, understanding how to best incentivize firms’ green transition is crucial. Our research highlights how green disclosure requirements can facilitate this transition, showing that their optimal design depends critically on the underlying characteristics of the transition technology. When early steps in the green transition are particularly costly, they can create roadblocks. In such cases, dynamic green disclosure requirements that become more stringent over time can most effectively promote the green transition by helping firms overcome these initial roadblocks while preserving long-term incentives for a complete transition.

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A Proofs Baseline Model

Proof of Lemma 1. The investor's end-of-period $t = 0$ valuation of a low-type green firm that scales the green technology in period $t = 0$ is given by

$$\hat{\pi} - \kappa_s + \lambda b_{gH} + \frac{\beta}{1 - \beta} (\pi + \lambda b_{gH}),$$

where $\hat{\pi}$ denotes the realization and π the expectation of the random profit $\tilde{\pi}$. The investor's end-of-period $t = 0$ valuation of an initially low-type green firm that does not scale the green technology in period $t = 0$, assuming the firm will not scale its technology in any future period, is given by

$$\hat{\pi} + \lambda b_{gL} + \frac{\beta}{1 - \beta} (\pi + \lambda b_{gL}).$$

The manager maximizes the investor's expected end-of-period valuation because scaling and adoption decisions are made before profits are realized. Clearly, the manager of an initially low-type green firm never delays the decision to scale the green technology. The manager of an initially low-type green firm thus scales the green technology in period $t = 0$ if and only if

$$\frac{\pi + \lambda b_{gH}}{1 - \beta} - \kappa_s \geq \frac{\pi + \lambda b_{gL}}{1 - \beta} \Leftrightarrow \frac{\lambda \Delta_s}{1 - \beta} \geq \kappa_s,$$

which completes the proof. ■

Proof of Lemma 2. Anticipating the scaling decision from Lemma 1, the investor's expected end-of-period $t = 0$ valuation of a dirty firm that adopts the green technology in period $t = 0$ is given by

$$\frac{\pi}{1 - \beta} - \kappa_a + \max \left\{ \frac{\lambda b_{gL}}{1 - \beta}, \frac{\lambda b_{gH}}{1 - \beta} - \kappa_s \right\},$$

which can be rewritten as

$$\frac{\pi + \lambda b_{gL}}{1 - \beta} - \kappa_a + \max \left\{ \frac{\lambda \Delta_s}{1 - \beta} - \kappa_s, 0 \right\}.$$

The valuation of a dirty firm that does not adopt the green technology in any period is given by $\frac{\pi + \lambda b_d}{1 - \beta}$. Thus, the manager of an initially dirty firm adopts the green technology in period $t = 0$ if and only if

$$\frac{\pi + \lambda b_{gL}}{1 - \beta} - \kappa_a + \max \left\{ \frac{\lambda \Delta_s}{1 - \beta} - \kappa_s, 0 \right\} \geq \frac{\pi + \lambda b_d}{1 - \beta},$$

which can be further rewritten as

$$\frac{\lambda \Delta_a}{1 - \beta} + \max \left\{ \frac{\lambda \Delta_s}{1 - \beta} - \kappa_s, 0 \right\} \geq \kappa_a,$$

completing the proof. ■

Proof of Corollary 1. The proof follows directly from Lemmas 1 and 2 by setting $\lambda = 1$. ■

Proof of Lemma 3. Consider an equilibrium in which a fraction of low-type green firms scale the green technology in period $t = 0$. Denote the resulting proportions of low- and high-type green firms in the green disclosure category at the end of period $t = 0$ by θ_{gL} and θ_{gH} , respectively.

The investor's expected end-of-period $t = 0$ valuation of a firm in the green disclosure category is thus given by

$$\frac{\pi + \theta_{gL} \lambda b_{gL} + \theta_{gH} \lambda b_{gH}}{1 - \beta} - \kappa,$$

where $\kappa \in \{0, \kappa_s, \kappa_a, \kappa_a + \kappa_s\}$. Recall that the investor only observes $\hat{\pi} - \kappa$ at the end of period $t = 0$ and cannot individually observe the adoption or scaling costs if the firm incurred them and, as we assume, cannot infer from the observation of $\hat{\pi} - \kappa$ whether or not the firm adopted or scaled the green technology.

The manager of an initially dirty firm that adopts the green technology or an initially low-type green firm does not scale the green technology since

$$\frac{\pi + \theta_{gL} \lambda b_{gL} + \theta_{gH} \lambda b_{gH}}{1 - \beta} - \kappa_s - \kappa < \frac{\pi + \theta_{gL} \lambda b_{gL} + \theta_{gH} \lambda b_{gH}}{1 - \beta} - \kappa,$$

where $\kappa \in \{\kappa_a, 0\}$. Thus, since the investor's expected valuation gross of the scaling cost is independent of the scaling decision, the manager does not scale the green technology. ■

Proof of Proposition 1. We consider two cases: (i) no dirty firm adopts the green technology, and (ii) a fraction $\phi \in (0, 1]$ of dirty firms adopt the green technology.

From Lemma 3, we know there is no scaling of the green technology under lax green disclosure requirements. Assuming that no dirty firm adopts the green technology, the investor's expected end-of-period $t = 0$ valuation of a dirty firm is given by $\frac{\pi + \lambda b_d}{1 - \beta}$, and the expected end-of-period $t = 0$ valuation of a firm in the green disclosure category is given by

$$\frac{\pi + \frac{\mu_{gL}}{\mu_{gL} + \mu_{gH}} \lambda b_{gL} + \frac{\mu_{gH}}{\mu_{gL} + \mu_{gH}} \lambda b_{gH}}{1 - \beta} - \kappa,$$

where $\kappa \in \{\kappa_a, 0\}$ depending on the manager's adoption decision. This equilibrium, therefore,

requires that no dirty firm adopts the green technology, that is,

$$\frac{\pi + \frac{\mu_{gL}}{\mu_{gL} + \mu_{gH}} \lambda b_{gL} + \frac{\mu_{gH}}{\mu_{gL} + \mu_{gH}} \lambda b_{gH}}{1 - \beta} - \kappa_a \leq \frac{\pi + \lambda b_d}{1 - \beta},$$

which can be rewritten as

$$\kappa_a \geq \bar{\kappa}_a := \frac{\lambda \Delta_a + \frac{\mu_{gH}}{\mu_{gL} + \mu_{gH}} \lambda \Delta_s}{1 - \beta} < \frac{\lambda (\Delta_a + \Delta_s)}{1 - \beta}.$$

Thus, no dirty firm adopts the green technology if $\kappa_a \geq \bar{\kappa}_a$.

Assuming that a fraction $\phi > 0$ of dirty firms adopt the green technology, the investor's expected end-of-period $t = 0$ valuation of a firm in the green disclosure category is given by

$$\frac{\pi + \frac{\phi \mu_d + \mu_{gL}}{\phi \mu_d + \mu_{gL} + \mu_{gH}} \lambda b_{gL} + \frac{\mu_{gH}}{\phi \mu_d + \mu_{gL} + \mu_{gH}} \lambda b_{gH}}{1 - \beta} - \kappa,$$

where $\kappa \in \{\kappa_a, 0\}$ depending on the manager's adoption decision. For the manager of a dirty firm to be willing to adopt the green technology requires

$$\frac{\pi + \frac{\phi \mu_d + \mu_{gL}}{\phi \mu_d + \mu_{gL} + \mu_{gH}} \lambda b_{gL} + \frac{\mu_{gH}}{\phi \mu_d + \mu_{gL} + \mu_{gH}} \lambda b_{gH}}{1 - \beta} - \kappa_a \geq \frac{\pi + \lambda b_d}{1 - \beta},$$

which can be rewritten as

$$\kappa_a \leq \frac{\lambda \Delta_a + \frac{\mu_{gH}}{\phi \mu_d + \mu_{gL} + \mu_{gH}} \lambda \Delta_s}{1 - \beta}.$$

Thus, if the inequality is satisfied for $\phi = 1$, that is,

$$\kappa_a \leq \frac{\lambda \Delta_a + \frac{\mu_{gH}}{\mu_d + \mu_{gL} + \mu_{gH}} \lambda \Delta_s}{1 - \beta},$$

then we have $\phi = 1$, and all dirty firms adopt the green technology. Define

$$\underline{\kappa}_a := \frac{\lambda \Delta_a + \frac{\mu_{gH}}{\mu_d + \mu_{gL} + \mu_{gH}} \lambda \Delta_s}{1 - \beta} > \frac{\lambda \Delta_a}{1 - \beta}.$$

Note also that clearly $\underline{\kappa}_a < \bar{\kappa}_a$. Thus, all dirty firms adopt the green technology if $\kappa_a \leq \underline{\kappa}_a$.

If $\kappa_a \in (\underline{\kappa}_a, \bar{\kappa}_a)$, there does not exist an equilibrium in which all dirty firms adopt the green technology, and there does not exist an equilibrium in which no dirty firm adopts the green technology. In this case, there exists an equilibrium in which a fraction $\phi \in (0, 1)$ of dirty firms adopt

the green technology, where ϕ is given implicitly by

$$\frac{\lambda\Delta_a + \frac{\mu_{gH}}{\phi\mu_d + \mu_{gL} + \mu_{gH}}\lambda\Delta_s}{1 - \beta} - \kappa_a = 0.$$

Solving the above equation for ϕ , we get that a fraction

$$\phi = \frac{1}{\mu_d} \left(\frac{\mu_{gH}\lambda\Delta_s}{(1 - \beta)\kappa_a - \lambda\Delta_a} - \mu_{gL} - \mu_{gH} \right) \in (0, 1)$$

of dirty firms adopt the green technology. In particular, ϕ is decreasing in κ_a . ■

Proof of Corollary 2. Note that the term

$$\frac{\lambda\Delta_a + \frac{\mu_{gH}}{\phi\mu_d + \mu_{gL} + \mu_{gH}}\lambda\Delta_s}{1 - \beta},$$

from the proof of Proposition 1 can be rewritten as

$$\frac{\lambda\Delta_a + \alpha \frac{\mu_{gL} + \mu_{gH}}{\phi\mu_d + \mu_{gL} + \mu_{gH}}\lambda\Delta_s}{1 - \beta}.$$

Note that for every $\phi \in [0, 1]$, the term is increasing in α when keeping μ_d (and therefore $\mu_{gL} + \mu_{gH}$) constant. The proof of Proposition 1 then implies that the thresholds $\underline{\kappa}_a$ and $\bar{\kappa}_a$ and the fraction ϕ are increasing in α . ■

Proof of Proposition 2. Assume that the inequality in equation (1) holds. If $\kappa_s \leq \frac{\lambda\Delta_s}{1 - \beta}$, under time-invariant strict green disclosure requirements, all dirty firms adopt and subsequently scale the green technology in period $t = 0$, and all initially low-type green firms scale the green technology in period $t = 0$. Under time-invariant lax green disclosure requirements, at most all dirty firms adopt the green technology in period $t = 0$, but no firm scales the green technology. Hence, the regulator prefers time-invariant strict green disclosure.

If $\kappa_s > \frac{\lambda\Delta_s}{1 - \beta}$, under time-invariant strict green disclosure requirements, all dirty firms adopt the green technology in period $t = 0$ but do not scale the green technology, and no initially low-type green firm scales the green technology. Under time-invariant lax green disclosure requirements, all dirty firms adopt the green technology in period $t = 0$, but no firm scales the green technology. Hence, the regulator is indifferent between the two time-invariant strict green disclosure requirements. Note that if the inequality in equation (1) holds and $\kappa_s > \frac{\lambda\Delta_s}{1 - \beta}$, then $\kappa_a \leq \frac{\lambda\Delta_a}{1 - \beta}$ such that all dirty firms adopt the green technology under time-invariant lax green disclosure requirements. ■

Proof of Proposition 3. Assume that the inequality in equation (1) is violated. Consider first the

case in which $\kappa_a < \bar{\kappa}_a$ and $\kappa_s > \frac{\lambda\Delta_s}{1-\beta}$. Then, under time-invariant strict green disclosure requirements, no dirty firm adopts the green technology, and no low-type green firm scales the green technology. In contrast, under time-invariant lax green disclosure requirements, a positive fraction of dirty firms adopt the green technology, and no low-type green firm scales the green technology. Hence, the regulator prefers time-invariant lax green disclosure.

Consider next the case in which $\kappa_a < \bar{\kappa}_a$ and $\kappa_s \leq \frac{\lambda\Delta_s}{1-\beta}$. Then, under time-invariant strict green disclosure requirements, no dirty firm adopts the green technology, but all initially low-type green firms scale the green technology. In contrast, under time-invariant lax green disclosure requirements, a positive fraction of dirty firms adopt the green technology, and no low-type green firm scales the green technology. Thus, the regulator prefers lax green disclosure requirements if the total expected social surplus under lax green disclosure requirements,

$$(1-\phi)\mu_d \frac{\pi+b_d}{1-\beta} + (\phi\mu_d + \mu_{gL}) \frac{\pi+b_{gL}}{1-\beta} + \mu_{gH} \frac{\pi+b_{gH}}{1-\beta} - \phi\mu_d\kappa_a,$$

exceeds the total expected social surplus under strict green disclosure requirements,

$$\mu_d \frac{\pi+b_d}{1-\beta} + (\mu_{gL} + \mu_{gH}) \frac{\pi+b_{gH}}{1-\beta} - \mu_{gL}\kappa_s,$$

which can be expressed as

$$\phi\mu_d \left(\frac{\Delta_a}{1-\beta} - \kappa_a \right) > \mu_{gL} \left(\frac{\Delta_s}{1-\beta} - \kappa_s \right).$$

If this inequality is not satisfied, the regulator prefers strict green disclosure or is indifferent between the two green disclosure requirements.

Further, if $\kappa_a \geq \bar{\kappa}_a$, there is no adoption and no scaling under lax green disclosure requirements, which implies that the regulator either prefers strict green disclosure (if low-type green firms scale the technology under strict green disclosure requirements, i.e., $\kappa_s \leq \frac{\lambda\Delta_s}{1-\beta}$) or is indifferent between the two green disclosure requirements. ■

Proof of Lemma 4. Consider first an equilibrium in which the regulator sets green disclosure requirements to lax at the beginning of period $t = 0$ and switches to strict green disclosure in the future as soon as they get the chance to do so. In this equilibrium, there is no scaling of the green technology until the green disclosure requirements become strict, and there may be adoption by a fraction of dirty firms. Note that if there is any adoption by dirty firms, it happens immediately in the first period since there is no reason to delay adoption for dirty firms. Thus, if the regulator switches to strict green disclosure requirements, low-type green firms scale the green technology if and only if $\frac{\lambda\Delta_s}{1-\beta} \geq \kappa_s$. If the regulator deviates to maintaining lax green disclosure requirements

in that period, there is no scaling by low-type green firms in that period, and there is also no further adoption by dirty firms since the adoption decision is identical to the first period. Thus, the regulator has no incentive to deviate, with a strict preference if $\frac{\lambda\Delta_s}{1-\beta} \geq \kappa_s$.

The same argument implies that an equilibrium in which the regulator does not switch to strict green disclosure requirements cannot exist if $\frac{\lambda\Delta_s}{1-\beta} \geq \kappa_s$ since deviating to implementing strict green disclosure requirements induces scaling whereas there is no further adoption and no scaling under lax green disclosure requirements. ■

Proof of Corollary 3. This result follows directly from the fact that if the inequality in equation (1) is violated and $\kappa_s > \frac{\lambda\Delta_s}{1-\beta}$, the investor's expected end-of-period $t = 0$ valuation in equation (5) is identical to the investor's expected end-of-period $t = 0$ valuation of a firm in the green disclosure category under time-invariant lax green disclosure requirements in equation (2). We can thus apply the proof of Proposition 1. ■

Proof of Proposition 4. Assume that the inequality in equation (1) is violated and that $\frac{\lambda\Delta_s}{1-\beta} > \kappa_s$. We have to consider two cases: (i) no dirty firm adopts the green technology, and (ii) a fraction $\phi^D \in (0, 1]$ of dirty firms adopt the green technology.

Assuming that no dirty firm adopts the green technology, the investor's expected end-of-period $t = 0$ valuation of a dirty firm is given by $\frac{\pi + \lambda b_d}{1-\beta}$, and of a firm in the green disclosure category is given by

$$\frac{\pi + \frac{\mu_{gL}}{\mu_{gL} + \mu_{gH}} \lambda b_{gL} + \frac{\mu_{gH}}{\mu_{gL} + \mu_{gH}} \lambda b_{gH}}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \frac{\mu_{gL}}{\mu_{gL} + \mu_{gH}} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right) - \kappa,$$

where $\kappa \in \{\kappa_a, 0\}$. This equilibrium, therefore, requires

$$\frac{\pi + \frac{\mu_{gL}}{\mu_{gL} + \mu_{gH}} \lambda b_{gL} + \frac{\mu_{gH}}{\mu_{gL} + \mu_{gH}} \lambda b_{gH}}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \frac{\mu_{gL}}{\mu_{gL} + \mu_{gH}} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right) - \kappa_a \leq \frac{\pi + \lambda b_d}{1 - \beta},$$

which can be rewritten as

$$\kappa_a \geq \bar{\kappa}_a^D := \frac{\lambda \Delta_a + \frac{\mu_{gH}}{\mu_{gL} + \mu_{gH}} \lambda \Delta_s}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \frac{\mu_{gL}}{\mu_{gL} + \mu_{gH}} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right) > \bar{\kappa}_a.$$

Thus, no dirty firm adopts the green technology if $\kappa_a \geq \bar{\kappa}_a^D$. Note that $\bar{\kappa}_a^D < \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$.

Assuming that a fraction $\phi^D > 0$ of dirty firms adopt the green technology, the investor's ex-

pected end-of-period $t = 0$ valuation of a firm in the green disclosure category is given by

$$\frac{\pi + \frac{\phi^D \mu_d + \mu_{gL}}{\phi^D \mu_d + \mu_{gL} + \mu_{gH}} \lambda b_{gL} + \frac{\mu_{gH}}{\phi^D \mu_d + \mu_{gL} + \mu_{gH}} \lambda b_{gH}}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \frac{\phi^D \mu_d + \mu_{gL}}{\phi^D \mu_d + \mu_{gL} + \mu_{gH}} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right) - \kappa,$$

where $\kappa \in \{\kappa_a, 0\}$. Note that this valuation is decreasing in ϕ^D . This equilibrium, therefore, requires

$$\kappa_a \leq \frac{\lambda \Delta_a + \frac{\mu_{gH}}{\phi^D \mu_d + \mu_{gL} + \mu_{gH}} \lambda \Delta_s}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \frac{\phi^D \mu_d + \mu_{gL}}{\phi^D \mu_d + \mu_{gL} + \mu_{gH}} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right).$$

Thus, if

$$\kappa_a \leq \frac{\lambda \Delta_a + \frac{\mu_{gH}}{\mu_d + \mu_{gL} + \mu_{gH}} \lambda \Delta_s}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \frac{\mu_d + \mu_{gL}}{\mu_d + \mu_{gL} + \mu_{gH}} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right),$$

then $\phi^D = 1$ and all dirty firms adopt the green technology. Define

$$\underline{\kappa}_a^D := \frac{\lambda \Delta_a + \frac{\mu_{gH}}{\mu_d + \mu_{gL} + \mu_{gH}} \lambda \Delta_s}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \frac{\mu_d + \mu_{gL}}{\mu_d + \mu_{gL} + \mu_{gH}} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right) > \underline{\kappa}_a.$$

Then, if $\kappa_a \leq \underline{\kappa}_a^D$, all dirty firms adopt the green technology. It is straightforward to show that $\underline{\kappa}_a^D < \bar{\kappa}_a^D$.

If $\kappa_a \in (\underline{\kappa}_a^D, \bar{\kappa}_a^D)$, there does not exist an equilibrium in which all dirty firms adopt the green technology, and there does not exist an equilibrium in which no dirty firm adopts the green technology. In this case, there exists an equilibrium in which a fraction $\phi^D \in (0, 1)$ of dirty firms adopt the green technology, where ϕ^D is given implicitly by

$$\frac{\lambda \Delta_a + \frac{\mu_{gH}}{\phi^D \mu_d + \mu_{gL} + \mu_{gH}} \lambda \Delta_s}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \frac{\phi^D \mu_d + \mu_{gL}}{\phi^D \mu_d + \mu_{gL} + \mu_{gH}} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right) - \kappa_a = 0.$$

Simple algebra verifies that $\phi^D > \phi$. Finally, since $\underline{\kappa}_a^D > \underline{\kappa}_a$ and $\bar{\kappa}_a^D > \bar{\kappa}_a$, we have $\phi^D \geq \phi$ with $\phi^D > \phi$ in some cases. ■

Proof of Proposition 4. The result follows directly from Lemmas 1 and 2, and Propositions 1 and 4. ■

Proof of Lemma 5. The proof follows directly from the derivations of $\underline{\kappa}_a^D$, $\bar{\kappa}_a^D$, and ϕ^D in the proof of Proposition 4. ■

Proof of Proposition 5. Assume that the inequality in equation (1) is violated. Consider first the case in which $\kappa_a < \bar{\kappa}_a^D$ and $\kappa_s > \frac{\lambda\Delta_s}{1-\beta}$. Then, under time-invariant strict green disclosure requirements, no dirty firm adopts the green technology, and no low-type green firm scales the green technology. In contrast, under dynamic green disclosure requirements, a positive fraction of dirty firms adopt the green technology, and no low-type green firm scales the green technology. Hence, the regulator prefers dynamic green disclosure requirements.

Second, consider the case in which $\kappa_a < \bar{\kappa}_a^D$ and $\kappa_s \leq \frac{\lambda\Delta_s}{1-\beta}$. Then, under time-invariant strict green disclosure requirements, no dirty firm adopts the green technology, but all initially low-type green firms scale the green technology. In contrast, under dynamic green disclosure requirements, a positive fraction of dirty firms adopt the green technology and scale it after green disclosure requirements become strict, and initially low-type green firms scale after green disclosure requirements become strict. The total expected discounted social surplus under dynamic green disclosure requirements, not including the initial adoption costs, denoted by W , satisfies

$$W = (1 - \phi^D)\mu_d(\pi + b_d) + (\phi^D\mu_d + \mu_{g_L})(\pi + b_{g_L}) + \mu_{g_H}(\pi + b_{g_H}) + \beta \left(\rho \left((1 - \phi^D)\mu_d \frac{\pi + b_d}{1 - \beta} + (\phi^D\mu_d + \mu_{g_L} + \mu_{g_H}) \frac{\pi + b_{g_H}}{1 - \beta} - (\phi^D\mu_d + \mu_{g_L})\kappa_s \right) + (1 - \rho)W \right).$$

The total expected discounted social surplus under dynamic green disclosure requirements net of the initial adoption costs is therefore given by

$$\frac{\pi + b_d}{1 - \beta} (1 - \phi^D)\mu_d + \frac{\pi + b_{g_L}}{1 - \beta} \frac{1 - \beta}{1 - \beta(1 - \rho)} (\phi^D\mu_d + \mu_{g_L}) + \frac{\pi + b_{g_H}}{1 - \beta} \left(\mu_{g_H} + \frac{\beta\rho}{1 - \beta(1 - \rho)} (\phi^D\mu_d + \mu_{g_L}) \right) - \frac{\beta\rho}{1 - \beta(1 - \rho)} (\phi^D\mu_d + \mu_{g_L})\kappa_s - \phi^D\mu_d\kappa_a.$$

The total expected discounted social surplus under strict green disclosure requirements is given by

$$\mu_d \frac{\pi + b_d}{1 - \beta} + (\mu_{g_L} + \mu_{g_H}) \frac{\pi + b_{g_H}}{1 - \beta} - \mu_{g_L}\kappa_s.$$

Thus, the regulator prefers dynamic to strict green disclosure requirements if and only if

$$\phi^D\mu_d \left(\frac{\Delta_a}{1 - \beta} - \kappa_a + \frac{\beta\rho}{1 - \beta(1 - \rho)} \left(\frac{\Delta_s}{1 - \beta} - \kappa_s \right) \right) > \mu_{g_L} \frac{1 - \beta}{1 - \beta(1 - \rho)} \left(\frac{\Delta_s}{1 - \beta} - \kappa_s \right).$$

If this inequality is not satisfied, the regulator prefers strict green disclosure or is indifferent between the two green disclosure requirements.

Further, if $\kappa_a \geq \bar{\kappa}_a^D$, there is no adoption and no scaling by dirty firms under dynamic green disclosure requirements, which implies that the regulator either prefers strict green disclosure re-

quirements or is indifferent between the two disclosure requirements. $\blacksquare$

Proof of Lemma 6. The result follows directly from the fact that the left-hand-side of inequality (6) is increasing in ρ , the right-hand-side of inequality (6) is decreasing in ρ , and $\bar{\kappa}_a^D$ is increasing in ρ . $\blacksquare$

B Proofs Model Extensions

Proof of Proposition 6. We consider dynamic green disclosure requirements, an equilibrium in which only high-type green firms voluntarily disclose their types when feasible, and a fraction $\hat{\phi}^D$ of dirty firms adopt the green technology in period $t = 0$. Note that in this proof, when we discuss the disclosure decisions of firms, firm type refers to the firm's status at the time it is endowed with the voluntary green disclosure technology before scaling occurs rather than its type at the end of the period.

Following similar steps as in Section 6.1, in this case, the valuation of a firm in the green disclosure category is given by

$$\frac{\pi + \hat{\theta}_{gL} \lambda b_{gL} + \hat{\theta}_{gH} \lambda b_{gH}}{1 - \beta} - \kappa + \frac{\beta \rho}{1 - \beta(1 - \rho)} \hat{\theta}_{gL} \max \left\{ \frac{\lambda \Delta_s}{1 - \beta} - \kappa_s, 0 \right\}, \quad (7)$$

where $\kappa = \kappa_a$ if the firm incurred the adoption cost and $\kappa = 0$ otherwise. The weights are given by $\hat{\theta}_{gL} = \frac{\hat{\phi}^D \mu_d + \mu_{gL}}{\hat{\phi}^D \mu_d + \mu_{gL} + (1 - \psi) \mu_{gH}}$ and $\hat{\theta}_{gH} = 1 - \hat{\theta}_{gL} = \frac{(1 - \psi) \mu_{gH}}{\hat{\phi}^D \mu_d + \mu_{gL} + (1 - \psi) \mu_{gH}}$. Thus, the valuation under voluntary green disclosure by high-type green firms differs from the valuation in the baseline model, given by (5), through the weights that reflect the lower fraction of high-type green firms in the green disclosure category because a fraction ψ of these firms are able to disclose their types.

We can then follow the structure of the proofs of Propositions 1 and 4 to study dirty firms' adoption decisions. Consider first the case in which $\frac{\lambda \Delta_s}{1 - \beta} < \kappa_s$. Replacing μ_{gH} with $(1 - \psi) \mu_{gH}$ in the proof of Proposition 1 and using $\hat{\phi}$ instead of $\hat{\phi}^D$ consistent with the notation of that proposition, we get that no dirty firm adopts the green technology if $\kappa_a \geq \bar{\hat{\kappa}}_a$, where

$$\kappa_a \geq \bar{\hat{\kappa}}_a := \frac{\lambda \Delta_a + \frac{(1 - \psi) \mu_{gH}}{\mu_{gL} + (1 - \psi) \mu_{gH}} \lambda \Delta_s}{1 - \beta} < \frac{\lambda (\Delta_a + \Delta_s)}{1 - \beta}.$$

In addition, we have $\bar{\hat{\kappa}}_a < \bar{\kappa}_a$, where $\bar{\kappa}_a$ is the threshold from Proposition 1.

Further, we get that if

$$\kappa_a \leq \hat{\kappa}_a := \frac{\lambda \Delta_a + \frac{(1 - \psi) \mu_{gH}}{\mu_d + \mu_{gL} + (1 - \psi) \mu_{gH}} \lambda \Delta_s}{1 - \beta} > \frac{\lambda \Delta_a}{1 - \beta},$$

then we have $\hat{\phi} = 1$, and all dirty firms adopt the green technology. In addition, we have $\hat{\kappa}_a < \kappa_a$, where κ_a is the threshold from Proposition 1. Note also that clearly $\hat{\kappa}_a < \bar{\kappa}_a$.

If $\kappa_a \in (\hat{\kappa}_a, \bar{\kappa}_a)$, there does not exist an equilibrium in which all dirty firms adopt the green technology, and there does not exist an equilibrium in which no dirty firm adopts the green technology. In this case, there exists an equilibrium in which a fraction $\hat{\phi} \in (0, 1)$ of dirty firms adopt the green technology, where $\hat{\phi}$ is given implicitly by

$$\frac{\lambda \Delta_a + \frac{(1-\psi)\mu_{gH}}{\hat{\phi}\mu_d + \mu_{gL} + (1-\psi)\mu_{gH}} \lambda \Delta_s}{1 - \beta} - \kappa_a = 0.$$

Solving the above equation for $\hat{\phi}$, we get that a fraction

$$\hat{\phi} = \frac{1}{\mu_d} \left(\frac{(1-\psi)\mu_{gH} \lambda \Delta_s}{(1-\beta)\kappa_a - \lambda \Delta_a} - \mu_{gL} - (1-\psi)\mu_{gH} \right) \in (0, 1)$$

of dirty firms adopt the green technology. In particular, $\hat{\phi}$ is decreasing in κ_a . Note also that whenever $\hat{\phi} \in (0, 1)$ and $\phi \in (0, 1)$, where ϕ is the threshold from Proposition 1, then we have $\hat{\phi} < \phi$.

Next consider the case in which $\frac{\lambda \Delta_s}{1-\beta} \geq \kappa_s$. Replacing μ_{gH} with $(1-\psi)\mu_{gH}$ in the proof of Proposition 4, we get that no dirty firm adopts the green technology if $\kappa_a \geq \bar{\kappa}_a^D$, where

$$\kappa_a \geq \bar{\kappa}_a^D := \frac{\lambda \Delta_a + \frac{(1-\psi)\mu_{gH}}{\mu_{gL} + (1-\psi)\mu_{gH}} \lambda \Delta_s}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \frac{\mu_{gL}}{\mu_{gL} + (1-\psi)\mu_{gH}} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right) > \bar{\kappa}_a.$$

Note that $\bar{\kappa}_a^D < \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$. In addition, it is straightforward to show that we have $\bar{\kappa}_a^D < \bar{\kappa}_a^D$, where $\bar{\kappa}_a^D$ is the threshold from Proposition 4.

Further, if

$$\kappa_a \leq \hat{\kappa}_a^D := \frac{\lambda \Delta_a + \frac{(1-\psi)\mu_{gH}}{\mu_d + \mu_{gL} + (1-\psi)\mu_{gH}} \lambda \Delta_s}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \frac{\mu_d + \mu_{gL}}{\mu_d + \mu_{gL} + (1-\psi)\mu_{gH}} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right),$$

then $\hat{\phi}^D = 1$ and all dirty firms adopt the green technology. It is straightforward to show that $\hat{\kappa}_a^D < \bar{\kappa}_a^D$ and $\hat{\kappa}_a^D < \kappa_a^D$, where κ_a^D is the threshold from Proposition 4.

If $\kappa_a \in (\hat{\kappa}_a^D, \bar{\kappa}_a^D)$, there does not exist an equilibrium in which all dirty firms adopt the green technology, and there does not exist an equilibrium in which no dirty firm adopts the green technology. In this case, there exists an equilibrium in which a fraction $\hat{\phi}^D \in (0, 1)$ of dirty firms adopt

the green technology, where $\hat{\phi}^D$ is given implicitly by

$$\frac{\lambda\Delta_a + \frac{(1-\psi)\mu_{gH}}{\hat{\phi}^D\mu_d + \mu_{gL} + (1-\psi)\mu_{gH}}\lambda\Delta_s}{1-\beta} + \frac{\beta\rho}{1-\beta(1-\rho)} \frac{\hat{\phi}^D\mu_d + \mu_{gL}}{\hat{\phi}^D\mu_d + \mu_{gL} + (1-\psi)\mu_{gH}} \left(\frac{\lambda\Delta_s}{1-\beta} - \kappa_s \right) - \kappa_a = 0.$$

In particular, $\hat{\phi}^D$ is decreasing in κ_a . Note also that whenever $\hat{\phi}^D \in (0, 1)$ and $\phi^D \in (0, 1)$, where ϕ^D is the threshold from Proposition 4, then we have $\hat{\phi}^D < \phi^D$.

Finally, we determine the equilibrium conditions regarding the voluntary green disclosure decisions. The equilibrium requires that high-type green firms with the voluntary green disclosure technology have no incentive to deviate to not disclosing. If a high-type green firm discloses, the firm's valuation is given by

$$\frac{\pi + \lambda b_{gH}}{1-\beta} - c,$$

and it is equal to (7) if it deviates to not disclosing. Thus, the equilibrium requires that

$$\frac{\pi + \lambda b_{gH}}{1-\beta} - c \geq \frac{\pi + \hat{\theta}_{gL}\lambda b_{gL} + \hat{\theta}_{gH}\lambda b_{gH}}{1-\beta} + \frac{\beta\rho}{1-\beta(1-\rho)} \hat{\theta}_{gL} \max \left\{ \frac{\lambda\Delta_s}{1-\beta} - \kappa_s, 0 \right\},$$

which can be rewritten as

$$\frac{\hat{\theta}_{gL}\lambda\Delta_s}{1-\beta} - \frac{\beta\rho}{1-\beta(1-\rho)} \hat{\theta}_{gL} \max \left\{ \frac{\lambda\Delta_s}{1-\beta} - \kappa_s, 0 \right\} =: \bar{c} \geq c.$$

Note that $\bar{c} > 0$ since

$$\frac{\lambda\Delta_s}{1-\beta} > \frac{\beta\rho}{1-\beta(1-\rho)} \max \left\{ \frac{\lambda\Delta_s}{1-\beta} - \kappa_s, 0 \right\}.$$

The equilibrium further requires that low-type green firms with the voluntary green disclosure technology have no incentive to deviate to disclosing their type. If a low-type green firm deviates to disclosing, then its valuation is given by

$$\frac{\pi + \lambda b_{gL}}{1-\beta} + \max \left\{ \frac{\lambda\Delta_s}{1-\beta} - \kappa_s, 0 \right\} - \kappa - c,$$

where $\kappa \in \{0, \kappa_a\}$, and it is equal to (7) if it does not deviate to not disclosing. Thus, the equilibrium requires that

$$\begin{aligned} \frac{\pi + \hat{\theta}_{gL}\lambda b_{gL} + \hat{\theta}_{gH}\lambda b_{gH}}{1-\beta} - \kappa + \frac{\beta\rho}{1-\beta(1-\rho)} \hat{\theta}_{gL} \max \left\{ \frac{\lambda\Delta_s}{1-\beta} - \kappa_s, 0 \right\} \geq \\ \frac{\pi + \lambda b_{gL}}{1-\beta} + \max \left\{ \frac{\lambda\Delta_s}{1-\beta} - \kappa_s, 0 \right\} - \kappa - c, \end{aligned}$$

which can be rewritten as

$$c \geq \underline{c} := -\frac{(1 - \hat{\theta}_{gL})\lambda\Delta_s}{1 - \beta} + \left(1 - \frac{\beta\rho}{1 - \beta(1 - \rho)}\hat{\theta}_{gL}\right) \max\left\{\frac{\lambda\Delta_s}{1 - \beta} - \kappa_s, 0\right\}.$$

We have $\underline{c} \leq \bar{c}$ if and only if

$$\frac{\lambda\Delta_s}{1 - \beta} \geq \max\left\{\frac{\lambda\Delta_s}{1 - \beta} - \kappa_s, 0\right\},$$

which is always satisfied. ■

Proof of Proposition 7. We consider dynamic green disclosure requirements and an equilibrium in which all high-type and low-type green firms with the voluntary green disclosure technology disclose their types. Note that in this proof, when we discuss the disclosure decisions of firms, firm type refers to the firm's status at the time it is endowed with the voluntary green disclosure technology before scaling occurs rather than its type at the end of the period. Let $\frac{\lambda\Delta_s}{1 - \beta} > \kappa_s$. In particular, after a low-type green firm decides to voluntarily disclose its type, it will scale the green technology. Following similar steps as in Section 6.1, in this case, the valuation of a firm in the green disclosure category is given by

$$\frac{\pi + \hat{\theta}_{gL}\lambda b_{gL} + \hat{\theta}_{gH}\lambda b_{gH}}{1 - \beta} - \kappa + \frac{\beta\rho}{1 - \beta(1 - \rho)}\hat{\theta}_{gL} \left(\frac{\lambda\Delta_s}{1 - \beta} - \kappa_s\right), \quad (8)$$

where $\kappa = \kappa_a$ if the firm incurred the adoption cost and $\kappa = 0$ otherwise. The weights are given by

$$\hat{\theta}_{gL} = \frac{(1 - \psi)\hat{\phi}^D\mu_d + (1 - \psi)\mu_{gL}}{(1 - \psi)\hat{\phi}^D\mu_d + (1 - \psi)\mu_{gL} + (1 - \psi)\mu_{gH}} = \frac{\hat{\phi}^D\mu_d + \mu_{gL}}{\hat{\phi}^D\mu_d + \mu_{gL} + \mu_{gH}},$$

and

$$\hat{\theta}_{gH} = 1 - \hat{\theta}_{gL} = \frac{(1 - \psi)\mu_{gH}}{(1 - \psi)\hat{\phi}^D\mu_d + (1 - \psi)\mu_{gL} + (1 - \psi)\mu_{gH}} = \frac{\mu_{gH}}{\hat{\phi}^D\mu_d + \mu_{gL} + \mu_{gH}}.$$

Thus, conditional on the fraction of dirty firms that adopt the green technology, the valuation is identical to (5) from Section 6.1 since the same fraction of low-type and high-type green firms disclose their types.

If a dirty firm adopts the green technology, its valuation is given by

$$\psi \left(\frac{\pi + \lambda b_{gH}}{1 - \beta} - \kappa_s - c \right) + (1 - \psi) \left(\frac{\pi + \hat{\theta}_{gL} \lambda b_{gL} + \hat{\theta}_{gH} \lambda b_{gH}}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \hat{\theta}_{gL} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right) \right) - \kappa_a.$$

If it does not adopt, the valuation is given by $\frac{\pi + \lambda b_d}{1 - \beta}$. Thus, the dirty firm adopts the green technology if the former valuation weakly exceeds the latter, which can be rewritten as

$$\frac{\psi}{1 - \psi} \left(\frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta} - \kappa_s - \kappa_a - c \right) + \frac{\lambda \Delta_a + \hat{\theta}_{gH} \lambda \Delta_s}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \hat{\theta}_{gL} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right) - \kappa_a \geq 0.$$

Note that when $\psi = 0$, we are back to the baseline model, and the proof of Proposition 4 applies exactly. When $\psi > 0$, the adoption incentives are weaker since $\frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta} - \kappa_s - \kappa_a < 0$ when the inequality in equation (1) is violated. Following the same steps as in the proof from Proposition 4, this implies that the fraction of dirty firms that adopt the green technology, $\hat{\phi}^D$, must weakly decline compared to the baseline model, with a strict decline in some cases.

Finally, we determine the conditions under which there is no deviation regarding the voluntary green disclosure decisions. The equilibrium requires that high-type green firms with the voluntary green disclosure technology have no incentive to deviate to not disclosing. If a high-type green firm discloses, then its valuation is given by

$$\frac{\pi + \lambda b_{gH}}{1 - \beta} - c,$$

and it is equal to (8) if it deviates to not disclosing. Thus, the equilibrium requires that

$$\frac{\pi + \lambda b_{gH}}{1 - \beta} - c \geq \frac{\pi + \hat{\theta}_{gL} \lambda b_{gL} + \hat{\theta}_{gH} \lambda b_{gH}}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \hat{\theta}_{gL} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right),$$

which can be rewritten as

$$\frac{\hat{\theta}_{gL} \lambda \Delta_s}{1 - \beta} - \frac{\beta \rho}{1 - \beta(1 - \rho)} \hat{\theta}_{gL} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right) =: \bar{c} \geq c.$$

Note that $\bar{c} > 0$ since

$$\frac{\lambda \Delta_s}{1 - \beta} > \frac{\beta \rho}{1 - \beta(1 - \rho)} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right).$$

The equilibrium further requires that low-type green firms with the voluntary green disclosure technology have no incentive to deviate to not disclosing. If a low-type green firm discloses, then

its valuation is given by

$$\frac{\pi + \lambda b_{gH}}{1 - \beta} - \kappa_s - \kappa - c,$$

where $\kappa \in \{0, \kappa_a\}$, and its valuation is equal to (8) if it deviates to not disclosing. Thus, the equilibrium requires that

$$\frac{\pi + \lambda b_{gH}}{1 - \beta} - \kappa_s - \kappa - c \geq \frac{\pi + \hat{\theta}_{gL} \lambda b_{gL} + \hat{\theta}_{gH} \lambda b_{gH}}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \hat{\theta}_{gL} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right) - \kappa,$$

which can be rewritten as

$$c \leq \underline{c} := -\frac{(1 - \hat{\theta}_{gL}) \lambda \Delta_s}{1 - \beta} + \left(1 - \frac{\beta \rho}{1 - \beta(1 - \rho)} \hat{\theta}_{gL} \right) \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right).$$

We have $\underline{c} < \bar{c}$ if and only if

$$\frac{\lambda \Delta_s}{1 - \beta} \geq \frac{\lambda \Delta_s}{1 - \beta} - \kappa_s,$$

which is always satisfied.

We further require that $\underline{c} > 0$, which requires

$$\hat{\theta}_{gL} \left(1 - \frac{\beta \rho}{1 - \beta(1 - \rho)} \right) \frac{\lambda \Delta_s}{1 - \beta} > \left(1 - \frac{\beta \rho}{1 - \beta(1 - \rho)} \hat{\theta}_{gL} \right) \kappa_s,$$

which is satisfied if $\hat{\theta}_{gL}$ is sufficiently high. A sufficient condition is that $\frac{\mu_{gL}}{\mu_{gL} + \mu_{gH}}$ is sufficiently high since $\hat{\theta}_{gL} \geq \frac{\mu_{gL}}{\mu_{gL} + \mu_{gH}}$. ■

Proof of Proposition 8. Consider the case in which κ_a is sufficiently low such that there is some adoption under dynamic green disclosure requirements in the extended model.

First, consider the case in which $\kappa_s > \frac{\lambda \Delta_s}{1 - \beta}$. Then, there is the benefit of a fraction of dirty firms adopting the green technology but no cost in terms of delaying scaling by low-type green firms. The regulator, therefore, prefers dynamic green disclosure requirements.

Second, consider the case in which $\kappa_s \leq \frac{\lambda \Delta_s}{1 - \beta}$. In the equilibrium from Proposition 6, there is no scaling of the green technology before the disclosure requirements become strict. Hence, we can follow the same steps as in the proof of Proposition 5.

In the equilibrium from Propositions 7, a fraction ψ of low-type green firms scale the green technology after disclosing their type in period $t = 0$. The total expected discounted social surplus under dynamic green disclosure requirements, not including the initial adoption and scaling costs,

denoted by W , satisfies

$$W = (1 - \hat{\phi}^D)\mu_d(\pi + b_d) + (1 - \psi)(\hat{\phi}^D\mu_d + \mu_{g_L})(\pi + b_{g_L}) + (\psi(\hat{\phi}^D\mu_d + \mu_{g_L}) + \mu_{g_H})(\pi + b_{g_H}) + \beta \left(\rho \left((1 - \hat{\phi}^D)\mu_d \frac{\pi + b_d}{1 - \beta} + (\hat{\phi}^D\mu_d + \mu_{g_L} + \mu_{g_H}) \frac{\pi + b_{g_H}}{1 - \beta} - (1 - \psi)(\hat{\phi}^D\mu_d + \mu_{g_L})\kappa_s \right) + (1 - \rho)W \right).$$

The total expected discounted social surplus under dynamic green disclosure requirements net of the initial adoption costs is therefore given by

$$\begin{aligned} & \frac{\pi + b_d}{1 - \beta} (1 - \hat{\phi}^D)\mu_d + \frac{\pi + b_{g_L}}{1 - \beta} \frac{1 - \beta}{1 - \beta(1 - \rho)} (1 - \psi)(\hat{\phi}^D\mu_d + \mu_{g_L}) + \\ & \frac{\pi + b_{g_H}}{1 - \beta} \left(\mu_{g_H} + \psi(\hat{\phi}^D\mu_d + \mu_{g_L}) + \frac{\beta\rho}{1 - \beta(1 - \rho)} (1 - \psi)(\hat{\phi}^D\mu_d + \mu_{g_L}) \right) \\ & - \frac{\beta\rho}{1 - \beta(1 - \rho)} (1 - \psi)(\hat{\phi}^D\mu_d + \mu_{g_L})\kappa_s - \psi(\hat{\phi}^D\mu_d + \mu_{g_L})\kappa_s - \hat{\phi}^D\mu_d\kappa_a. \end{aligned}$$

The total expected discounted social surplus under strict green disclosure requirements is given by

$$\mu_d \frac{\pi + b_d}{1 - \beta} + (\mu_{g_L} + \mu_{g_H}) \frac{\pi + b_{g_H}}{1 - \beta} - \mu_{g_L}\kappa_s.$$

Thus, the regulator prefers dynamic to strict green disclosure requirements if and only if

$$\begin{aligned} & \hat{\phi}^D\mu_d \left(\frac{\Delta_a}{1 - \beta} - \kappa_a + \left(\psi + \frac{\beta\rho}{1 - \beta(1 - \rho)} (1 - \psi) \right) \left(\frac{\Delta_s}{1 - \beta} - \kappa_s \right) \right) > \\ & (1 - \psi)\mu_{g_L} \frac{1 - \beta}{1 - \beta(1 - \rho)} \left(\frac{\Delta_s}{1 - \beta} - \kappa_s \right). \end{aligned}$$

If this inequality is not satisfied, the regulator prefers strict green disclosure or is indifferent between the two green disclosure requirements. ■

Proof of Proposition 9. First, consider the case in which $\kappa_s > \frac{\lambda\Delta_s}{1 - \beta}$. Thus, a low-type green firm never scales the green technology under any information environment. Then, assuming a fraction $\hat{\phi}$ of dirty firms adopt the green technology, the end-of-period valuation of such a firm is given by

$$\xi \frac{\pi + \lambda b_{g_L}}{1 - \beta} + (1 - \xi) \frac{\pi + \frac{(1 - \xi)(\hat{\phi}\mu_d + \mu_{g_L})}{(1 - \xi)(\hat{\phi}\mu_d + \mu_{g_L}) + (1 - \xi)\mu_{g_H}} \lambda b_{g_L} + \frac{(1 - \xi)\mu_{g_H}}{(1 - \xi)(\hat{\phi}\mu_d + \mu_{g_L}) + (1 - \xi)\mu_{g_H}} \lambda b_{g_H}}{1 - \beta} - \kappa_a,$$

which can be rewritten as

$$\xi \frac{\pi + \lambda b_{gL}}{1 - \beta} + (1 - \xi) \frac{\pi + \frac{\hat{\phi} \mu_d + \mu_{gL}}{\hat{\phi} \mu_d + \mu_{gL} + \mu_{gH}} \lambda b_{gL} + \frac{\mu_{gH}}{\hat{\phi} \mu_d + \mu_{gL} + \mu_{gH}} \lambda b_{gH}}{1 - \beta} - \kappa_a,$$

In particular, relative to the valuation in our baseline model given by (2), the valuation is lower, reducing the incentives of a dirty firm to adopt the green technology. We can thus apply the steps in the proof of Proposition 1 to derive the equilibrium thresholds for dirty firms' adoption decisions and the equilibrium fraction of dirty firms that adopt the green technology. In particular, the results stated in the proposition follow directly from the fact that dirty firms have a weaker incentive to adopt the green technology when there is the signal.

Consider next the case in which $\kappa_s \leq \frac{\lambda \Delta_s}{1 - \beta}$. If a dirty firm adopts the green technology, the valuation is given by

$$\xi \left(\frac{\pi + \lambda b_{gH}}{1 - \beta} - \kappa_s \right) + (1 - \xi) \left(\frac{\pi + \hat{\theta}_{gL} \lambda b_{gL} + \hat{\theta}_{gH} \lambda b_{gH}}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \hat{\theta}_{gL} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right) \right) - \kappa_a,$$

where $\hat{\theta}_{gL} = 1 - \hat{\theta}_{gH} = \frac{\hat{\phi}^D \mu_d + \mu_{gL}}{\hat{\phi}^D \mu_d + \mu_{gL} + \mu_{gH}}$. If it does not adopt, the valuation is given by $\frac{\pi + \lambda b_d}{1 - \beta}$. Thus, the dirty firm adopts the green technology if

$$\frac{\xi}{1 - \xi} \left(\frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta} - \kappa_s - \kappa_a \right) + \frac{\lambda \Delta_a + \hat{\theta}_{gH} \lambda \Delta_s}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \hat{\theta}_{gL} \left(\frac{\lambda \Delta_s}{1 - \beta} - \kappa_s \right) - \kappa_a \geq 0.$$

When $\xi = 0$, we are back to the baseline model, and the proof from Proposition 4 applies exactly. When $\xi > 0$, the adoption incentives are weaker since $\frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta} - \kappa_s - \kappa_a < 0$ when the inequality in equation (1) is violated, implying that the fraction of dirty firms that adopt, $\hat{\phi}^D$, must be weakly lower compared to the baseline model, and strictly lower in some cases. ■

Proof of Proposition 10. We can apply the proof of Proposition 8 for the case in which both high-type and low-type green firms disclose their types and simply replace ψ with ξ . ■

C Alternative Green Disclosure Requirements

Proof of Proposition 11. First, consider the time-invariant case (i.e., $\rho = 0$). Note that dirty firms may adopt but will never also scale the green technology because they would get the same valuation as they do without adoption but incur a cost. Denote the share of dirty firms that adopt by ϕ_a and the share of low-type green firms that scale by ϕ_s . Then, the valuation of a firm in the pooled

disclosure category is given by

$$\frac{\pi + \frac{(1-\phi_a)\mu_d}{(1-\phi_a)\mu_d + \phi_s\mu_{gL} + \mu_{gH}}\lambda b_d + \frac{\phi_s\mu_{gL} + \mu_{gH}}{(1-\phi_a)\mu_d + \phi_s\mu_{gL} + \mu_{gH}}\lambda b_{gH}}{1-\beta} - \kappa,$$

where $\kappa \in \{0, \kappa_s\}$. Pooling dirty and high-type green firms weakly lowers the valuation of a high-type green firm relative to strict green disclosure. As a result, it lowers the incentive of a low-type green firm to scale the green technology relative to strict green disclosure. Further, since it strictly increases the valuation of a dirty firm relative to strict green disclosure, it lowers the incentive of a dirty firm to adopt the green technology relative to strict green disclosure. Thus, strict green disclosure weakly dominates time-invariant pooling of dirty and high-type green firms.

Next, consider the dynamic case (i.e., $\rho > 0$). When $\kappa_a > \frac{\lambda\Delta_a}{1-\beta}$ and $\kappa_s > \frac{\lambda\Delta_s}{1-\beta}$, then the time-invariant and dynamic cases are equivalent. In particular, the regulator is indifferent between switching to strict green disclosure requirements because no adoption or scaling takes place under either type of disclosure requirements.

When $\kappa_a \leq \frac{\lambda\Delta_a}{1-\beta}$ and $\kappa_s > \frac{\lambda\Delta_s}{1-\beta}$, then there is adoption by any remaining dirty firms after a switch to strict green disclosure. However, this further reduces the incentive to adopt the green technology in period $t = 0$ under pooled disclosure requirements as it introduces an option value of adoption. In particular, adoption incentives are weakly stronger under strict green disclosure, and scaling does not occur under either pooled or strict disclosure requirements.

When $\kappa_a > \frac{\lambda\Delta_a}{1-\beta} + \left(\frac{\lambda\Delta_s}{1-\beta} - \kappa_s\right)$ and $\kappa_s \leq \frac{\lambda\Delta_s}{1-\beta}$, then there is scaling after a switch to strict green disclosure. However, this further reduces the incentive to scale the green technology in period $t = 0$ under pooled disclosure requirements as it introduces an option value of scaling, which increases the valuation of a low-type green firm. In particular, scaling incentives are weakly stronger under strict green disclosure, and adoption does not occur under either pooled or strict disclosure requirements.

When $\kappa_a \leq \frac{\lambda\Delta_a}{1-\beta} + \left(\frac{\lambda\Delta_s}{1-\beta} - \kappa_s\right)$ and $\kappa_s \leq \frac{\lambda\Delta_s}{1-\beta}$, then strict green disclosure implements first-best and pooling dirty and high-type green firms cannot dominate. ■

Proof of Lemma 7. The result follows immediately from the arguments in the text. ■

Proof of Proposition 12. First, we show that if $\kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$, there exists a unique equilibrium in which $\phi_{a,s} = 0$ and $\phi_s = 0$. Note that $\frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$ is the largest possible valuation gain a firm can obtain from leaving the pooled disclosure category in any equilibrium. Thus, since $\kappa_a + \kappa_s > \kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$, no firm has an incentive to adopt or scale the green technology and we must have $\phi_{a,s} = 0$ and $\phi_s = 0$.

Next, we show that if $\kappa_s + \kappa_a \leq \frac{\lambda(\Delta_s + \Delta_a)}{1-\beta}$, there exists an equilibrium in which $\phi_{a,s} = 1$ and $\phi_s = 1$. Consider an equilibrium with $\phi_{a,s} = 1$ and $\phi_s = 1$. An initially low-type green firm has no

incentive to deviate if

$$\frac{\pi + \lambda b_{gH}}{1 - \beta} - \kappa_s \geq \frac{\pi + \lambda b_d}{1 - \beta} \Leftrightarrow \kappa_s \leq \frac{\lambda(\Delta_s + \Delta_a)}{1 - \beta}.$$

An initially dirty green firm has no incentive to deviate if

$$\frac{\pi + \lambda b_{gH}}{1 - \beta} - \kappa_s - \kappa_a \geq \frac{\pi + \lambda b_d}{1 - \beta} \Leftrightarrow \kappa_s + \kappa_a \leq \frac{\lambda(\Delta_s + \Delta_a)}{1 - \beta}.$$

Clearly, a superior equilibrium does not exist.

Next, we show that if $\kappa_s \leq \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta}$ and $\kappa_a + \kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta}$, there exists an equilibrium in which $\phi_{a,s} = 0$ and $\phi_s = 1$. Since $\kappa_a + \kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta}$, we can never have an equilibrium in which $\phi_{a,s} > 0$ since $\frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta}$ is the largest possible valuation gain a firm can obtain from leaving the pooled disclosure category in any equilibrium. Thus, we must have $\phi_{a,s} = 0$.

When $\phi_{a,s} = 0$, an initially low-type green firm scales the green technology if

$$\frac{\pi + \lambda b_{gH}}{1 - \beta} - \kappa_s \geq \frac{\pi + \lambda b_d + \frac{(1 - \phi_s)\mu_{gL}}{\mu_d + (1 - \phi_s)\mu_{gL}} \lambda \Delta_a}{1 - \beta},$$

which is equivalent to

$$\kappa_s \leq \frac{\lambda(\Delta_a + \Delta_s) - \frac{(1 - \phi_s)\mu_{gL}}{\mu_d + (1 - \phi_s)\mu_{gL}} \lambda \Delta_a}{1 - \beta} = \frac{\lambda \Delta_s + \frac{\mu_d}{\mu_d + (1 - \phi_s)\mu_{gL}} \lambda \Delta_a}{1 - \beta},$$

which is satisfied for $\phi_s = 1$.

Finally, note that a superior equilibrium cannot exist since we can never have an equilibrium with $\phi_{a,s} > 0$. ■

Proof of Lemma 8. When $\kappa_s \leq \frac{\lambda \Delta_s}{1 - \beta}$, then strict green disclosure implements the same transition as time-invariant pooling at the bottom.

When $\kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta}$, then time-invariant pooling at the bottom generates no transition, whereas strict green disclosure and time-invariant pooling at the top may generate some adoption. Thus, time-invariant pooling at the top and strict green disclosure weakly dominate time-invariant pooling at the bottom. ■

Proof of Proposition 13. In this proof, we prove the following more general result:

Proposition C.1. When $\frac{\lambda \Delta_s}{1 - \beta} < \kappa_s \leq \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta}$, there are three cases:

1. When $\kappa_a + \kappa_s \leq \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta}$, then time-invariant pooling at the bottom implements first-best

and therefore dominates all green disclosure requirements from the baseline model.

2. When $\kappa_a + \kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$ and $\kappa_a < \bar{\kappa}_a$, where $\bar{\kappa}_a$ is given in Proposition 1, then time-invariant pooling at the bottom may be optimal if the social value of the scaling it generates dominates the social value of adoption generated by time-invariant pooling at the top.
3. When $\kappa_a + \kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$ and $\kappa_a \geq \bar{\kappa}_a$, then time-invariant pooling at the bottom dominates all green disclosure requirements from the baseline model since it generates scaling whereas the green disclosure requirements in the baseline model generate no transition.

To prove this result, let $\frac{\lambda\Delta_s}{1-\beta} < \kappa_s \leq \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$ and consider three cases:

Case 1: $\kappa_a + \kappa_s \leq \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$. Time-invariant pooling at the bottom implements first-best and no disclosure requirements from the baseline model implement first-best because they cannot incentivize scaling. Thus, time-invariant pooling at the bottom dominates.

Case 2: $\kappa_a + \kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$ and $\kappa_a < \bar{\kappa}_a$. Time-invariant pooling at the bottom generates $\phi_{a,s} = 0$ and $\phi_s = 1$. Time-invariant pooling at the top weakly dominates strict green disclosure and generates some adoption but no scaling. Thus, there is a trade-off between the social value of scaling through pooling at the bottom and the social value of adoption through pooling at the top.

Case 3: $\kappa_a + \kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$ and $\kappa_a \geq \bar{\kappa}_a$. Time-invariant pooling at the bottom generates $\phi_{a,s} = 0$ and $\phi_s = 1$. None of the disclosure requirements in the baseline model generate any transition. Thus, time-invariant pooling at the bottom dominates. ■

Proof of Lemma 9. Case 1: $\kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$. Then, under dynamic pooling at the bottom, we must also have $\phi_{a,s} = \phi_s = 0$ as in the time-invariant case since $\frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$ is the largest possible valuation gain from leaving the pooled disclosure category even under dynamic pooling at the bottom. As a result, the regulator strictly prefers strict green disclosure or dynamic pooling at the top if these requirements induce adoption in period $t = 0$ and is indifferent otherwise. Thus, dynamic green disclosure requirements with pooling at the bottom are weakly dominated by the ones considered in our baseline model.

Case 2: $\kappa_s \leq \frac{\lambda\Delta_s}{1-\beta}$ and $\kappa_a \leq \frac{\lambda\Delta_a}{1-\beta} + \left(\frac{\lambda\Delta_s}{1-\beta} - \kappa_s\right)$. Then strict green disclosure implements first-best such that dynamic pooling at the bottom cannot dominate.

Case 3: $\kappa_s \leq \frac{\lambda\Delta_s}{1-\beta}$ and $\kappa_a > \frac{\lambda\Delta_a}{1-\beta} + \left(\frac{\lambda\Delta_s}{1-\beta} - \kappa_s\right)$. Note first that since $\kappa_a + \kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$, there cannot exist an equilibrium with $\phi_{a,s} > 0$ under dynamic pooling at the bottom since $\frac{\lambda(\Delta_a + \Delta_s)}{1-\beta}$ is the largest possible valuation gain a dirty firm can obtain from leaving the pooled disclosure category in any equilibrium. Thus, dynamic pooling at the bottom must generate $\phi_{a,s} = 0$. As a result, strict green disclosure weakly dominates dynamic pooling at the bottom. ■

Proof of Proposition 14. In this proof, we prove the following more general result:

Proposition C.2. Consider the case $\frac{\lambda\Delta_s}{1-\beta} < \kappa_s \leq \frac{\lambda(\Delta_a+\Delta_s)}{1-\beta}$. Under dynamic pooling at the bottom, there are four cases:

1. If $\kappa_s + \kappa_a \leq \frac{\lambda(\Delta_s+\Delta_a)}{1-\beta}$, there exists an equilibrium in which $\phi_{a,s} = 1$ and $\phi_s = 1$, and the regulator does not switch to strict green disclosure. Further, there does not exist an equilibrium that generates higher welfare.
2. If $\kappa_s + \kappa_a > \frac{\lambda(\Delta_s+\Delta_a)}{1-\beta}$, $\kappa_a \leq \frac{\lambda\Delta_a}{1-\beta}$, and

$$\kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta} - \frac{\beta\rho}{1 - \beta(1 - \rho)} \left(\frac{\lambda\Delta_a}{1 - \beta} - \kappa_a \right),$$

there exists an equilibrium in which $\phi_{a,s} = 0$ and $\phi_s = 0$ in period $t = 0$, the regulator switches to strict green disclosure, after which all dirty firms adopt but do not scale the green technology. Further, there does not exist an equilibrium that generates higher welfare.

3. If $\kappa_s + \kappa_a > \frac{\lambda(\Delta_s+\Delta_a)}{1-\beta}$, $\kappa_a \leq \frac{\lambda\Delta_a}{1-\beta}$, and

$$\kappa_s \leq \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta} - \frac{\beta\rho}{1 - \beta(1 - \rho)} \left(\frac{\lambda\Delta_a}{1 - \beta} - \kappa_a \right),$$

there exists an equilibrium in which $\phi_{a,s} = 0$ and $\phi_s = 1$, the regulator switches to strict green disclosure, after which all dirty firms adopt the green technology. Further, there does not exist an equilibrium that generates higher welfare.

4. If $\kappa_a > \frac{\lambda\Delta_a}{1-\beta}$, there exists an equilibrium in which $\phi_{a,s} = 0$ and $\phi_s = 1$, and the regulator is indifferent between switching and not switching to strict green disclosure since there is no further adoption or scaling after a switch to strict. Further, there does not exist an equilibrium that generates higher welfare.

To prove this result, note that when $\frac{\lambda\Delta_s}{1-\beta} < \kappa_s \leq \frac{\lambda(\Delta_a+\Delta_s)}{1-\beta}$, there are four cases:

Case 1: $\kappa_s + \kappa_a \leq \frac{\lambda(\Delta_s+\Delta_a)}{1-\beta}$. Note that the regulator can implement the first-best equilibrium derived under time-invariant pooling at the bottom (i.e., when $\rho = 0$) also under dynamic pooling at the bottom (i.e., when $\rho > 0$). The reason is that when $\phi_{a,s} = \phi_s = 1$, the regulator is indifferent between switching and not switching to strict green disclosure. Assuming that the regulator does not switch to strict green disclosure, the ex-ante incentives of firms to adopt and scale are identical to the time-invariant case. Clearly, there does not exist a superior equilibrium.

Cases 2 and 3: $\kappa_s + \kappa_a > \frac{\lambda(\Delta_s+\Delta_a)}{1-\beta}$ and $\kappa_a \leq \frac{\lambda\Delta_a}{1-\beta}$. Note first that since $\kappa_a + \kappa_s > \frac{\lambda(\Delta_a+\Delta_s)}{1-\beta}$, there cannot exist an equilibrium with $\phi_{a,s} > 0$ under dynamic pooling at the bottom since $\frac{\lambda(\Delta_a+\Delta_s)}{1-\beta}$ is the largest possible valuation gain a firm can obtain from leaving the pooled disclosure category in any

equilibrium. Thus, under dynamic pooling at the bottom, we consider an equilibrium in which no dirty firm adopts the green technology in period $t = 0$ and a fraction $\phi_s \in [0, 1]$ of initially low-type green firms scale the green technology.

Clearly, the regulator strictly prefers to switch to strict green disclosure since $\kappa_a \leq \frac{\lambda \Delta_a}{1-\beta}$. The expected valuation of a firm in the pooled disclosure category is given by

$$\underbrace{\frac{\pi + \theta_d \lambda b_d + \theta_{gL} \lambda b_{gL}}{1 - \beta}}_{\text{Valuation without adoption}} + \underbrace{\frac{\beta \rho}{1 - \beta(1 - \rho)} \theta_d \left(\frac{\lambda \Delta_a}{1 - \beta} - \kappa_a \right)}_{\text{Valuation boost from adoption}},$$

which can be rewritten as

$$\underbrace{\frac{\pi + \lambda b_d + \theta_{gL} \lambda \Delta_a}{1 - \beta}}_{\text{Valuation without adoption}} + \underbrace{\frac{\beta \rho}{1 - \beta(1 - \rho)} \theta_d \left(\frac{\lambda \Delta_a}{1 - \beta} - \kappa_a \right)}_{\text{Valuation boost from adoption}},$$

and where

$$\theta_d = \frac{\mu_d}{\mu_d + (1 - \phi_s) \mu_{gL}}$$

and

$$\theta_{gL} = 1 - \theta_d = \frac{(1 - \phi_s) \mu_{gL}}{\mu_d + (1 - \phi_s) \mu_{gL}}.$$

Thus, an equilibrium with $\phi_s = 1$ requires

$$\frac{\pi + \lambda b_d}{1 - \beta} + \frac{\beta \rho}{1 - \beta(1 - \rho)} \left(\frac{\lambda \Delta_a}{1 - \beta} - \kappa_a \right) \leq \frac{\pi + \lambda b_{gH}}{1 - \beta} - \kappa_s,$$

which is equivalent to

$$\kappa_s \leq \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta} - \frac{\beta \rho}{1 - \beta(1 - \rho)} \left(\frac{\lambda \Delta_a}{1 - \beta} - \kappa_a \right).$$

If this inequality is satisfied, then dynamic pooling at the bottom generates $\phi_s = 1$.

If this inequality is not satisfied, then we cannot have an equilibrium with $\phi_s = 1$. Note that the valuation is decreasing in ϕ_s , such that when the inequality is not satisfied, we can only have an equilibrium with $\phi_s = 0$. Thus, if the inequality is not satisfied, we have $\phi_{a,s} = \phi_s = 0$, and there is adoption after the switch to strict.

Note also that there cannot exist a superior equilibrium.

Case 4: $\kappa_a > \frac{\lambda \Delta_a}{1-\beta}$. There is no adoption and no scaling after a switch to strict green disclosure. In particular, the regulator is indifferent to switching to strict green disclosure. The equilibrium that is implemented is identical to the one under time-invariant pooling at the bottom from Proposition

12 with $\phi_{a,s} = 0$ and $\phi_s = 1$. In particular, there cannot exist a superior equilibrium. ■

Proof of Proposition 15. Proposition 14 and the results from the baseline model immediately imply the following more general result:

Proposition C.3. *Consider the case $\frac{\lambda\Delta_s}{1-\beta} < \kappa_s \leq \frac{\lambda(\Delta_a+\Delta_s)}{1-\beta}$. There are four cases:*

1. *If $\kappa_s + \kappa_a \leq \frac{\lambda(\Delta_s+\Delta_a)}{1-\beta}$, then dynamic pooling at the bottom implements first-best and therefore dominates all green disclosure requirements from the baseline model.*

2. *If $\kappa_s + \kappa_a > \frac{\lambda(\Delta_s+\Delta_a)}{1-\beta}$, $\kappa_a \leq \frac{\lambda\Delta_a}{1-\beta}$, and*

$$\kappa_s > \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta} - \frac{\beta\rho}{1 - \beta(1 - \rho)} \left(\frac{\lambda\Delta_a}{1 - \beta} - \kappa_a \right),$$

then dynamic pooling at the bottom can generate adoption only in the future and is therefore dominated by strict green disclosure, which generates adoption in period $t = 0$.

3. *If $\kappa_s + \kappa_a > \frac{\lambda(\Delta_s+\Delta_a)}{1-\beta}$, $\kappa_a \leq \frac{\lambda\Delta_a}{1-\beta}$, and*

$$\kappa_s \leq \frac{\lambda(\Delta_a + \Delta_s)}{1 - \beta} - \frac{\beta\rho}{1 - \beta(1 - \rho)} \left(\frac{\lambda\Delta_a}{1 - \beta} - \kappa_a \right),$$

then dynamic pooling at the bottom is optimal if the social value of scaling in period $t = 0$ with future adoption after the switch to strict green disclosure it generates dominates the social value of full adoption in period $t = 0$ generated by strict green disclosure.

4. *If $\kappa_s + \kappa_a > \frac{\lambda(\Delta_s+\Delta_a)}{1-\beta}$, $\kappa_a > \frac{\lambda\Delta_a}{1-\beta}$ and $\kappa_a < \bar{\kappa}_a$, where $\bar{\kappa}_a$ is in Proposition 1, then dynamic pooling at the bottom is optimal if the social value of scaling in period $t = 0$ it generates dominates the social value of adoption in period $t = 0$ generated by dynamic pooling at the top.*

5. *If $\kappa_s + \kappa_a > \frac{\lambda(\Delta_s+\Delta_a)}{1-\beta}$, $\kappa_a > \frac{\lambda\Delta_a}{1-\beta}$ and $\kappa_a \geq \bar{\kappa}_a$, then dynamic pooling at the bottom is optimal since it generates scaling in period $t = 0$, which dominates no transition under any green disclosure requirements from the baseline model.*

This completes the proof. ■

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